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THE SOILS AND CROPS OF THE MARKET-GARDEN DISTRICT OF BIGGLESWADE.

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INTRODUCTION.

WITHIN the last two or three years the attention of the agricultural world has been directed to the importance of the correlation of the chemical and physical properties of soils with the crops and systems of agriculture which farmers have found most suitable to them.

By such correlations many facts of supreme interest have been elicited. The American Bureau of Soils have been able to enumerate the characteristics and properties of various soil formations which render them suitable for some particular crop. They have been able to suggest new and more profitable crops as likely to be suitable for soils which have not hitherto grown them. They have been able to explain causes of fertility and infertility which have a practicable bearing not only on the agriculture of their own country but of the whole world.

Hall and Russell[1] were similarly able to demonstrate the value of a soil and crop survey to agriculture as a whole, and particularly to that of the district under their investigation. As a result of their work, they were able to give much advice on the improvement of methods of agriculture, mixtures of artificial manures suitable for the crops on each soil formation, the value of liming, etc.

Perhaps as a work of reference, a soil survey is of the greatest and most permanent value, for if the soils of a district have been classified and their properties stated in terms of mechanical and chemical analyses it becomes possible to compare abnormal soils with the normal soil type and to detect more readily the cause of its abnormality.

[1] Hall and Russell, *Agriculture and Soils of Kent, Surrey and Sussex.* Published by the Board of Agriculture and Fisheries, 1911.

Although soil surveys are in progress in many counties of England, and although much valuable information concerning the chemical and physical properties of different soil formations which make them suitable for ordinary cereal and root crops has been obtained, yet no similar work has been done on the market-garden soils and crops which play so important a part in the agriculture of such a county as Bedfordshire.

The area under market-garden crops increases yearly, and as there is a tendency for small farmers without experience to take up this particular branch of farming, it becomes more and more imperative that such correlations between crops, methods of agriculture, and chemical and physical properties of the soil should be made, in order to supply the inexperienced market-gardener with information concerning the most suitable crops and best systems of treatment and manuring for any soil formation of known properties.

Further, the minute survey of the soils necessary to achieve this end, in a district where there are great "quarternary" accumulations which vary considerably in texture, should throw some light upon the methods of soil survey applicable to counties where there is much "drift" deposit.

At the suggestion of Professor Wood, the writer decided to conduct a detailed examination of the soils and crops of the Biggleswade market-garden area of Bedfordshire. This area is roughly one of 100 square miles, and extends from Henlow in the south to St Neots in the north. Gamlingay marks the eastern limit and perhaps Willington marks an ill-defined western limit to the district. The Great Northern Railway runs through the centre of the district from north to south, giving St Neots, Tempsford, Sandy, Biggleswade, Langford, and Henlow direct connection with London, and communication with the great northern industrial centres, while the London and North-Western Railway crosses the Great Northern Railway almost at right angles and links up Gamlingay, Potton, Sandy, Girtford, Blunham, and Willington with the Midland Railway service to London and midland centres, map 1.

The district is characterized by extensive valley gravel deposits on either side of the Ivel and the Ouse. The Ivel flows almost due north and south, making a slight deviation around the western extremity of the greensand escarpment at Sandy, and joins its waters with the Ouse at Tempsford. The whole valley system of the Ouse and Ivel is enclosed by boulder clay elevations on the east and west.

The market-garden area proper can be said to lie within the limits of a two mile boundary on either side of the railway, but the writer has

gone rather farther afield in order to compare the soils of the immediate vicinity with those used for intensive market-garden culture. This investigation has, however, been primarily concerned with the market-garden soils, and therefore one or two heavy soil formations not suitable for the growth of market-garden crops but included in the investigation have not received perhaps the same detailed examination as those on which market-garden crops are extensively grown.

The investigation may be conveniently divided into three parts. Part I dealing with the methods employed in soil mapping and the relationship of the soil formations to the underlying geological formations. Part II a description of the properties and agriculture of the soil formations and a definition of their properties in terms of chemical and mechanical analyses. Part III the relationship of crops to the soil formations.

PART I.

Methods of Soil Mapping, Soil Definitions and Relationship of the Soil Formations to the Surface Geology.

In conducting any soil survey the first question which arises is the means of distinguishing between different soil types.

The American Bureau of Soils in their extensive surveys have classified soils in "series" according to their structure and colour. Under the "series" name will occur soils which have the "series" characteristic but yet which differ widely in texture. Thus the well-known Miami Series is characterized by the light colour of the surface soils and their derivation from glacial material. There are fourteen members of this series and the variation in texture is from gravel and sand to a clay loam. Thus geological origin largely decides series, but the position in the series, whether the conventional terms sand, gravel, clay, etc., should be applied to the soil, is determined by mechanical analysis.

Hall and Russell in their survey of Kent, Surrey and Sussex used the geological map as a basis on which to work in mapping soil formations. In this region the soils are comparatively uniform over an entire geological outcrop. In some instances, notably the Lower Wealden Beds, a greater variation in texture was found but the soils all had certain features in common, the high percentage of silt being particularly noticeable. Owing to the circumstance that this formation

possesses little agricultural interest, Hall and Russell made only a very rough division into areas of different texture.

In the market-garden district dealt with in this paper there are large areas where the texture of the original soil has been greatly altered by alluvial wash; there are very extensive valley gravel deposits which are subject to varying texture and structure; and lastly boulder clay deposits give rise to soils in some cases quite different from the majority of boulder clay soils.

Since market-garden crops, as will afterwards be shown, are susceptible to even slight variations in soil texture, it became necessary to map out the extent of all variations occurring on the geological formation before any correlation of crop and soil could be attempted.

The writer has followed Hall and Russell in using the geological formation to mark the extent of a series of soils which have a somewhat similar mineral structure. These series of soils have, however, then been separated into soil formations having different agricultural properties and the extent of each has been mapped.

For the purpose of mapping the soil formations, the six inch Ordnance Survey maps, which show the fields, were used. Every field was examined in a detailed way over the whole area. Field observations of the colour, texture, the agricultural operations and general surface features were used in determining the extent of each soil formation. The six inch maps were then reduced to the one inch scale from which map 4 was constructed showing the various soil formations in the district.

The following geological formations were examined and the series of soils occurring on them were divided into soil formations which had different agricultural properties:

(1) Oxford clay giving rise to two soil formations:
- (*a*) Pure clay soil,
- (*b*) A clay loam probably resulting from an alluvial wash on to the clay soil.

(2) Greensand giving rise to two soil formations:
- (*a*) Dark sands,
- (*b*) Brown sands.

(3) Gault giving rise to two soil formations:
- (*a*) Pure clay soil,
- (*b*) A sandy loam locally known as "Redland," occurring as a narrow strip between greensand and the pure gault clay soil (*a*).

(4) Boulder clay giving rise to three soil formations:
- (a) Pure boulder clay soil,
- (b) Heavy loam produced by wash on boulder clay,
- (c) Sandy loam produced by a thin capping of boulder clay on greensand.

(5) Brick earths giving rise to only one soil formation.

(6) Glacial giving rise to one soil formation, which, however, is not quite so uniform as the brick earth formation.

(7) Valley gravels giving rise to three soil formations:
- (a) A brown soil formation (referred to as "Old Brown"),
- (b) A heavy brown soil formation,
- (c) A more recent dark soil formation (referred to as "New Dark").

Samples of soil from each soil formation were then collected and submitted to chemical and mechanical analysis using the methods adopted by the Agricultural Education Association[1].

By this means, not only was it possible to verify the field observations in referring soils to distinct soil formations, but the soil formations were thus defined by a conventional method which admitted comparison of the soils with those of other parts of England and foreign countries. A glance at the results of analysis in the Appendix will show that not only has mechanical and chemical analysis differentiated between the various soil formations but an extraordinary uniformity between the samples taken from any soil formation is revealed, e.g. the greensand soils. This series of soils is differentiated from any other by the low percentage of potash and mineral salts and an almost entire absence of calcium carbonate. The coarse sand fraction is particularly high and this fact alone would be almost sufficient to distinguish it from any other series.

The uniformity of the samples collected from different parts of a soil formation is well illustrated in the case of these soils. In five soils from the brown sands the following variations were found:—

K_2O	varies between	·22–·25
P_2O_5	,,	·24–·29
$CaCO_3$	,,	·06–·09
Al_2O_3, Fe_2O_3	,,	9·34–11·87
Coarse sand	,,	51·0–59·4

[1] *Journ. of Agric. Sci.* I. p. 470.

In the case of the dark sands we have the following variations for two samples taken:

K_2O	varies between	·13–·18
P_2O_5	,,	·11–·19
$CaCO_3$	,,	·08–·09
Fe_2O_3, Al_2O_3	,,	8·70–8·79
Coarse sand	,,	54·6–57·2

The dark sand seems to be differentiated from the brown sands by a much lower content of potash and phosphoric acid.

To take one more example, the Oxford clay soils may be considered. The Oxford clay formation has been divided into two soil formations (*a*) pure clay soils, (*b*) clay loams.

Class (*a*) is characterized by the following:

Coarse sand	14·8
Clay	29·5
$CaCO_3$	·12
K_2O	1·18
P_2O_5	·09
Fe_2O_3, Al_2O_3	15·4

Class (*b*) had the following variations in three samples analysed:

Coarse sand	varies between	20·0–23·3
Clay	,,	19·7–21·2
$CaCO_3$	,,	·06–·70
K_2O	,,	·74–·76
P_2O_5	,,	·08–·19*
Fe_2O_3, Al_2O_3	,,	10·30–11·52

The results of chemical analysis are sufficient to distinguish the Oxford clay series from all the other clay formations dealt with in this paper, for the percentage of calcium carbonate and phosphoric acid is extremely low in all the samples taken from this series.

Again mechanical analysis at once reveals the necessity for a sub-division into two soil formations, since there is a constant difference of 9 per cent. in the percentage of clay found in the two soil formations mapped from field observations.

The following table shows the average of analyses of soils on each soil formation in terms of mechanical and chemical analysis.

* The sample containing ·19 per cent. had ·043 per cent. more available P_2O_5 than any other soil in this formation and it is probable that this has been added in manures.

Definition of Soil Formations by Analysis.

	Greensand		Valley gravel			Boulder clay			Glacial	Oxford clay		Gault		Brick earths
	Brown	Dark	Old	New	Heavy	Al. wash	Pure	G. sand		Pure	Al.	Pure	Rd. ld.	
Mechanical analysis:														
Stones	6·6	8·2	11·6	9·8	5·8	7·9	4·3	5·2	5·7	1·8	1·7	7·5	2·6	2·4
Fine gravel	7·3	6·3	4·3	2·8	1·7	1·8	1·5	2·9	2·9	1·9	1·2	1·2	2·9	1·7
Coarse sand	55·2	55·9	48·3	35·5	34·1	27·5	15·9	46·8	25·5	14·8	21·8	15·3	35·1	28·3
Fine sand	12·7	13·8	18·1	19·5	21·8	18·5	14·2	18·9	20·1	9·8	16·7	12·8	17·1	18·0
Coarse silt	8·5	8·2	11·7	12·9	12·3	10·4	11·5	9·7	10·5	13·1	14·9	9·4	11·9	13·7
Fine silt	4·4	2·7	4·8	7·0	7·7	7·9	11·4	5·6	9·0	16·1	12·2	12·9	9·0	10·3
Clay	4·4	4·7	6·1	10·3	12·9	17·9	23·6	8·7	17·4	29·5	20·6	29·3	13·4	15·1
Moisture	1·26	1·29	0·9	2·0	1·0	2·6	3·7	·9	3·2	5·0	3·2	4·5	2·3	2·0
Org. matter	4·9	4·8	4·0	6·6	6·0	6·6	6·1	5·0	5·8	8·3	6·7	7·4	5·7	5·7
$CaCO_3$	·07	·09	·11	·58	·38	3·15	5·63	·08	2·7	·12	·41	3·5	·15	·80
Chemical analysis:														
Insol. residue	82·7	84·8	87·1	80·8	82·1	73·5	67·5	83·4	74·9	68·7	77·1	65·4	80·1	78·9
K_2O	·23	·15	·24	·37	·45	·65	·82	·41	·68	1·18	·75	·97	·52	·51
P_2O_5	·27	·15	·22	·26	·17	·17	·15	·28	·34	·09	·13	·19	·22	·14
Fe_2O_3, Al_2O_3	10·3	8·7	7·3	8·3	9·1	11·9	13·2	9·5	10·8	15·4	10·9	15·8	10·4	9·5
CaO	·20	·20	·32	1·03	·87	2·4	4·35	·30	2·27	·65	·81	3·09	·41	1·19
MgO	·20	·14	·24	·37	·42	·44	·62	·30	·52	·67	·51	·74	·38	·43

Relationship of Soil Formations to Surface Geology.

It is of some interest to compare the soil formations with the geological formations and to ascertain the agencies which have produced varying types of soil, and maps 2 and 4 have been drawn to the same scale in order that the two sets of formations may be readily compared.

The geological map has been pieced together from numerous six inch maps which the Geological Survey Office kindly placed at my disposal. The lower half of the map has been published on the one inch scale, but the only maps obtainable for the upper half were the unpublished draft sheets at the Survey Office. Under these circumstances it is probable that the accuracy of the geological map is not very great in minor details, for this map has not been revised since the first survey was made.

In the case of boulder clay cappings resting on greensand, two small areas, marked B^1, D on the geological map 2, seem to have disappeared. It is quite probable that the thin capping of boulder clay, once existing here, has been disturbed by coprolite digging.

Again, two areas A, A^1 are marked on map 2 as belonging to the brown valley gravel soil formation but the geological map shows boulder clay and brick earths in these two spots. There appears to the present writer to be considerable evidence for mapping the geology of these areas as valley gravels. The surface features point clearly to these areas as a continuation of the main valley gravel formation marked A^2, map 2. The valley gravel formation is certainly continuous over the area A and, in the case of the area A^1, there is only a narrow depression of clay separating it from the main area A^2, map 2. The area A^1 moreover is an elevated gravel soil which appears undoubtedly at one time to have been linked up with the main area A^2. Gravels consisting of broken flints have been dug up from both the areas A and A^1 and these gravels are exactly similar to those underlying the main gravel soil formation A^2, map 2. A comparison of the following analyses reveals the similarity of the topsoil and the subsoil of the supposed valley gravel areas A and A^1 with the main valley gravel formation A^2, map 2. Analyses of brick earth and boulder clay soils in the vicinity are also given for purposes of comparison.

Not only does the analysis of the supposed valley gravel topsoil agree in every respect with that of the known valley gravel soil, but the subsoils are also identical and are widely divergent from the boulder clay and brick earth soils in the immediate vicinity. Since the geologist

classifies surface geology by a consideration of the subsoil, the areas A, A^1 should be classed as valley gravels.

The area B, map 2, which appears on the geological map as boulder clay, seems, from field observations, to be rather different in texture from boulder clay soils. The soil is a darkish loam containing numerous small flints. A deposit of valley gravel material seems to have sufficiently altered the surface soil to justify its being classed as belonging to the valley gravel soil formation.

	Supposed valley gravels		Known valley gravels		Brick earths		Boulder clay	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
Sample......	107	108	89	90	29	30	15	16
Mechanical Analysis:								
Stones	8·9	8·3	10·7	11·4	2·4	5·3	3·4	5·8
Fine gravel	3·4	3·1	3·3	3·7	1·8	2·8	1·9	1·4
Coarse sand	50·1	47·2	46·6	46·5	27·4	30·6	19·5	20·5
Fine sand	18·8	20·3	19·6	20·0	16·9	18·1	11·5	13·5
Coarse silt	10·0	10·1	11·1	12·0	11·6	11·1	9·9	—
Fine silt	5·1	5·4	5·2	5·7	11·2	8·7	10·5	—
Clay	6·6	8·9	5·7	6·7	15·4	15·5	23·5	—
Moisture	·60	·68	1·45	·95	1·82	2·42	4·11	—
Org. matter	4·27	3·00	5·12	3·25	8·75	7·40	8·83	—
$CaCO_3$	·03	—	·085	—	1·47	—	7·38	—
Chemical Analysis:								
Insol. residue	88·27	88·88	85·98	88·03	76·52	76·48	66·22	—
K_2O	·27	·31	·27	·31	·52	·54	·80	—
P_2O_5	·18	·15	·24	·19	·16	·14	·16	—
Al_2O_3, Fe_2O_3	6·20	6·80	6·67	6·60	9·61	10·17	13·49	—
CaO	·31	·25	·42	·36	1·78	2·24	4·84	—
MgO	·26	·27	·23	·25	·45	·50	·55	—

With the exception of these small areas indicated above, each soil series coincides in area with a geological formation.

The chief agencies producing different soil formations in the soil series are (1) river wash causing deposition of coarser grained material on the Oxford clay and boulder clay formations.

(2) Slight changes in upper and lower beds of a geological formation: e.g. in greensand the dark sands are always overlying the brown sands, and redland is held by Mr Teall[1] to be a transition bed between greensand and gault.

[1] Dr Bonney, *Geology of Cambridgeshire.*

(3) Variations in the depth of boulder clay cappings: e.g. boulder clay on greensand is usually a sandy loam.

(4) Variation in material deposited by different river systems: e.g. old brown and new dark gravel soil formations.

PART II.

Soil Formations—their characteristic properties and agriculture.

1. Oxford Clay Series.

Dr Bonney[1] states that the Neocomian deposits of this part of Bedfordshire rest upon Oxford clay, the higher members of the Jurassic clay series being absent. Reed[2] states that the Ampthill clay is worked at Everton, but describes the lower greensand at Sandy as resting on Oxford clay. Under these circumstances it is rather a remarkable fact that soils taken from the extensive Oxford clay plain between Sandy and Tempsford should resemble Kimeridge clay soils closely in composition.

F. W. Foreman[3] describes the Kimeridge clay soils which he had collected from a number of widely separated districts as being dark brown soils, devoid of lime. He says that the dark colour distinguishes them quite readily from Oxford clay soils which are light coloured and well supplied with lime.

The present writer found that the Oxford clay soils in the district investigated were invariably very dark brown in colour and resembled the Kimeridge clay soils described by Foreman in an almost complete absence of calcium carbonate. The following are the actual percentages of calcium carbonate found by Foreman compared with the percentages found by the present writer.

	Foreman's results		*The writer's results*	
	Kimeridge clay[4] mean 2 analyses	Oxford clay mean 3 analyses	Soil from Everton	Soils from Sandy-Tempsford plain
$CaCO_3$	·18	4·07	·12	·27

Whether this plain between Sandy and Tempsford is Kimeridge or Oxford clay is a matter for the geologist and not the agriculturist

[1] Dr Bonney, *Geology of Cambridgeshire.*

[2] F. R. C. Reed, *A Handbook to the Geology of Cambridgeshire.*

[3] F. W. Foreman, "Soils of Cambridgeshire." *Journ. Agric. Sci.* vol. II. pt. 2.

[4] Foreman (*loc. cit.*) describes one soil as containing 33 per cent. $CaCO_3$ but states that this soil is purely local in extent and not characteristic of Kimeridge clay.

to decide. It is, however, a matter of considerable importance in soil survey work, for if samples from the same geological formation show such regular variation in areas not remotely separated, additional care must be taken in interpreting the results of soil analyses as typical of the whole formation.

The Oxford clay series has been divided into two soil formations.

(*a*) *The pure clay formation.*

This formation stretches out as a low-lying plain to the north of the greensand escarpment which runs through Everton and terminates at Sandy. An area of similar soil has been mapped to the east of Northill and Southill. The formation is a dark brown clay of the heaviest description. Batchelor[1] describes this soil as "a dark poor soil, coming too loose after frosts, infected by the worst of grasses, and of such general properties as to keep the cultivators poor." Owing to the slight fall to the river Ivel, the land is difficult to drain and is very wet in winter. This is particularly so of the great area to the north of Sandy and Everton. Here the poorness of the land and the low price of corn has resulted in hundreds of acres being allowed to run wild, so that now rank scrub, hawthorn, and wild rose stretch almost continuously from Everton to Tempsford. Much of this land thirty or forty years ago was in cultivation, and old inhabitants state that fair crops with plenty of straw could always be obtained. When the fall in price of wheat occurred, evidently the labour of cultivation was too high to bring a profitable return.

A few cattle are run on the pasture where it is reasonably free from scrub, but the pasture is of the very poorest, and moss seems to predominate. The land where it is cultivated grows wheat, mangel seed, horse beans, oats, clover and tares. Ploughing must always be done before Christmas or insuperable difficulties will prevent its cultivation in the Spring. The land is so wet that late Spring has arrived before it is fit to be touched, and even then the cultivator runs a good deal of risk of his newly ploughed land baking into hard intractable lumps.

The best farmers in the district all emphasize the importance of leaving one-quarter of the acreage of the farm fallow every year. The land is so infested with couch and other noxious grasses that fallowing once in four years becomes a necessity. A four-course rotation of wheat, beans, oats, fallow is usually adopted. The average yield of wheat is 28 bushels and of oats 40 bushels.

[1] Batchelor, *Survey of Bedfordshire*, p. 12.

The Oxford clay soil to the west of Northill and Southill is rather better drained, and a slightly better type of farming is possible. Much of the land, however, is in comparatively poor pasture and woodland. Where the land is cultivated, the crops previously mentioned are grown. Usually wheat, oats and clover do fairly well, but the yield of wheat and oats is disappointing on thrashing. Mangel seed seems to be the most profitable crop for this heavy land.

Composition. Mechanical and chemical analysis reveal that this soil contains a very high percentage of the clay fraction—the highest of all the clay formations occurring in the district—and a great poverty of calcium carbonate and phosphoric acid. The potash and the iron and alumina content are both very high as one would expect in such a heavy clay soil.

The available plant food as determined by Dyer's 1 per cent. citric acid method shows a sufficiency of potash but a great deficiency in phosphoric acid. A phosphatic manure such as basic slag should be particularly valuable in the improvement of poor pasture and for all crops grown on these heavy soils.

(*b*) *Clay loam formation.*

As previously explained this formation has probably originated from an intermixture of alluvial wash with the underlying clay. It is considerably lighter in texture than the formation just considered, but it shares with it a dark brown colour and a somewhat shaley appearance. This formation is remarkably uniform throughout both areas mapped which are widely separated by the Ivel gravels.

This formation is almost entirely under cultivation, and when well manured grows good mangels, mangel seed, wheat, oats and horse beans. Brussels sprouts, late potatoes, onions, parsley and small seeds are also grown, but this formation is not very suitable for market-garden crops as the soil is somewhat heavy, and it is rather difficult of access for carting dung or produce.

Composition. This formation contains 9 per cent. less clay than the pure clay formation, with a corresponding increase in the sand fractions. The phosphoric acid is slightly higher, while the potash is a good deal lower than in the case of the pure clay formation. The phosphoric acid content at first sight appears to vary rather widely in the three samples taken from this formation. One sample, however, has been heavily manured and contains ·051 per cent. available phosphoric acid. Probably ·045 per cent. of this has been added in manures and the total content for purposes of comparison should be

lowered by this percentage. The calcium carbonate content varies from ·06 to ·70 per cent., the higher figure representing the area to the south of Girtford. The area north of Sandy is low in calcium carbonate. The available plant food determinations show a sufficiency of potash but rather a low percentage of phosphoric acid, particularly in the area to the north of Sandy.

This formation is commonly manured with a light dressing of dung and a fairly large dressing of soot. Supplementary phosphatic manures such as basic slag or basic superphosphate should be valuable under these circumstances.

2. GREENSAND SERIES.

The greensand soils have been grouped into two soil formations.

(*a*) *The dark sand formation.*

This formation occurs on the escarpment of greensand between Sandy and Everton. The dark sands always seem to overlie the brown sand formation, for the dark sands are seldom more than a foot deep except on the slopes where the depth may be nearly 2 feet.

A pit on the escarpment between Sandy and Everton showed:

Grey sands	9 inches.
Carstone	1 foot.
Bright yellow sands.	

The dark sand formation is extensively covered with fir and larch plantations, but these are gradually being removed to give room for more profitable market-gardening.

Batchelor[1] describes the greensand soils as being too hilly for cultivation, and comments upon the two types of sand to be seen in the district. He says that the grey sands are invariably poorer than the brown sands and that they grow common heath (*Erica vulgaris*) and poor grasses. The present writer has also noticed this, but while Batchelor ascribes the poverty of the dark sands to a lower percentage of iron, the real reason seems to lie in a very much lower percentage of plant food.

The following figures are averages for brown and dark sands showing the percentage of iron and alumina, potash and phosphoric acid.

	Brown sands	Dark sands	Flitwick dark sand
K_2O	·23	·15	·23
P_2O_5	·27	·15	·16
Fe_2O_3, Al_2O_3	10·3	8·7	4·70

[1] Batchelor, *Survey of Bedfordshire.*

It will be observed that the percentages of potash and phosphoric acid are very much lower in the case of the dark sands. Hall and Russell[1] found a similar low content of plant food in the uncultivated sands of the Folkestone Beds.

The dark sand formation is now extensively used for market-garden crops. The usual procedure is to grow early potatoes followed by white turnips. Sometimes early potatoes are grown as half crops with brussels sprouts or runner beans. In a few cases late potatoes are planted after taking off a crop of early potatoes. The land must be exceedingly well dunged. Thirty tons to the acre with sixty bushels of soot is commonly used on this formation.

The extensive slopes towards Sandy face the sun and are particularly early soils. These slopes are very uniform in texture and contain few stones and little gravel. Their situation, fine even texture, and depth make the soils on these slopes particularly suited to the growth of radishes and early carrots. Radishes and carrots are sown broadcast very early in February. The radishes are ready for picking in March and gradually give way to early carrots which are ready in the second week of June. Frequently parsley seed is sown among the carrots and this is ready for cutting in November and December.

It would seem, at first sight, strange that radishes are not grown on the brown sand formation. This seems to be due to the fact that the dark sand formation, particularly on the slopes just referred to, has a fine even texture and contains only a small percentage of stones and gravel. At Flitwick, another market-garden centre of Bedfordshire, the writer noticed that radishes were grown on dark greensand soils.

The following figures show the salient points of difference from the brown sand formation.

	Brown sand formation (average)	Dark sand formation (slopes facing) Sandy	Flitwick dark sand
Stones	6·6	3·9	2·3
Fine gravel	7·3	2·5	1·0
Coarse sand	55·2	66·6	68·2
Fine sand	12·7	10·5	15·5
		Radish soils	

The dark sand formation is reported by market-gardeners as being not quite so "hungry" as the brown sand formation and particularly is this so on the Sandy slopes. The custom on these slopes seems to be dung one year and soot the next.

[1] Hall and Russell, *Agriculture and Soils of Kent, Surrey and Sussex*. Published by the Board of Agriculture and Fisheries, 1911.

Composition. The dark sand formation is characterized by very low percentages of phosphoric acid, potash, and calcium carbonate.

The soil[1] of the slopes facing Sandy is a good deal richer than the soil of the plateau above. This is due to the wash of the finer material from the plateau. The percentage of phosphoric acid in sample 47 is very high for this formation, but the available plant food is also very high and probably ·1 per cent. of phosphoric acid has been added by intense manuring.

(*b*) *The brown sand formation.*

This formation extends from Everton through Potton to Gamlingay and is almost entirely devoted to market-garden crops. Wonderful changes must have been effected since 1875 when Dr Bonney[2] described it as very sterile and as supporting little but Scotch firs. The crops grown on the brown sand formation are exactly similar to those grown on the plateau of the dark sand formation. Early potatoes are the important crop. They are followed by white turnips which grow through the Autumn and are pulled in November and December. In almost every case, the large turnips not suitable for marketing are cut up and ploughed in, and quite frequently if the crop is slightly inferior and prices are low the whole crop is turned under for green manure.

The large farmers on this formation, especially those whose farms are partly on heavy land, usually grow "full" crops of market-garden produce and are satisfied with one good crop a year. They winter or keep a number of cattle, more for the sake of the manure which is made than for a profit on the cattle. They generally run a small flock of sheep which is folded on the ground with kohlrabi and summer cabbages. There is no definite system of rotation of crops on these sand lands, and particularly is this so in the case of the small market-gardeners.

The large farmers seem to arrange their crops so as to give as much rest to the land as possible between crops. Cereals are grown once in four years further to sweeten the land. The following are examples of the general procedure: brussels sprouts, late potatoes, wheat or oats, late potatoes, early potatoes, late potatoes.

Brussels sprouts and potatoes are usually dunged with 25 to 30 tons of London dung. Sometimes the dung is put on the sprouts alone and the following crop of potatoes receives a large dressing of soot.

[1] Sample 47, Appendix.

[2] *Loc. cit.*

Composition. The brown sand formation is characterized by its high percentage of coarser particles. Thus stones and fine gravel average 13·9 per cent. while the coarse sand is 55·2 per cent. The fine silt and clay fractions are very small and the clay contains a large percentage of iron.

Chemical analysis reveals a great deficiency of calcium carbonate, a great uniformity in the percentage of potash (·22 per cent.) and a fairly high percentage of phosphoric acid. The content of calcium and magnesium salts is extremely small, but the available plant food is decidedly above the average. Probably there has been a storage of plant food due to excessive manuring, for these soils in pasture show only small quantities of available potash and phosphoric acid.

The success of the crops on this sand formation depends to a large extent on the rainfall during the period of growth. The soils are so coarse that little rise of subsoil water can take place. The problem is to introduce sufficient organic matter into the soil to conserve the water. The organic matter must be, however, of such a nature as will not open up the soil too much and let out the moisture.

3. The Gault Series.

(*a*) *Pure clay soil formation.*

This soil formation occurs as a narrow strip running between the redland soil formation and the boulder clay hills from Gamlingay to Sutton. Small areas also occur near Henlow and Stanford.

It is a particularly heavy bluish clay which is invariably wet and badly drained. This is noticeably so of the Gamlingay strip, where the drainage waters from the boulder clay hills find their way on to the surface of the gault which has been scooped out to form a long narrow depression. This soil is too heavy for market-garden crops and consequently it is used for ordinary farming purposes. It is generally farmed in conjunction with a strip of lighter land such as redland or the boulder clay on greensand formation. When drained it grows good wheat crops which, however, thrash somewhat lightly, the average yield being a little over 3 quarters per acre.

Horse beans, mangel seed, wheat and clover are the chief crops grown on the formation. Clover and sainfoin do well on this soil and give two good cuts a year.

Composition. The gault clay formation is characterized by a very high percentage of clay, 29·3 per cent., and a high percentage of calcium

carbonate, 3·5 per cent. Its content of calcium carbonate distinguishes it from the Oxford clay formation which in other details resembles the gault clay formation very closely. The high percentage of clay on the other hand distinguishes it from the boulder clay soil formation which is also rich in calcium carbonate.

The potash, iron and alumina percentages are both exceedingly high while the phosphoric acid content is higher than any other pure clay soil formation in this district. Determinations of the available plant food by Dyer's method show that this soil formation has a potash content above the average, but is somewhat poor in phosphoric acid.

For spring sown crops superphosphate should be very suitable while basic slag should be an effective supplementary dressing for autumn wheat and beans, considering the wet and heavy condition of the soil.

(*b*) *The redland soil formation.*

This formation occurs as a narrow strip between the greensand and pure gault clay formations. The formation is a little over a quarter of a mile wide and runs right through from Gamlingay to Sutton.

It possesses very characteristic properties which necessitate careful handling of the soil. It must not be ploughed or cultivated while wet if it is likely to be caught in a hot sun. Should this happen it forms hard steely lumps which remain in this condition until the frosts of winter crumble them.

For this reason, the redland formation is not suitable for market-garden crops, although late potatoes and brussels sprouts are grown to some extent. Mangels and kohlrabi do well on this soil, while oats, wheat and barley are also extensively grown. A rotation of beans, wheat, roots, barley is practised by more than one farmer. This formation gives fairly good yields if suitably manured. Thus wheat averages 4–5 quarters, barley averages 5–6 quarters, mangels average 30 tons.

Composition. The texture of the redland soil formation must necessarily be somewhat uneven owing to a surface wash of greensand which grades the redland soil off into the pure brown sand formation. Sample 39 perhaps would represent the typical redland soil better than any other, but an average of the three analyses given is sufficient to give a fairly true picture of the mechanical composition and mineral constituents of this soil formation.

This formation is a coarse sandy loam deficient in calcium carbonate. The potash content ·52 per cent. and phosphoric acid ·2 per cent. lie between the percentages found in the greensand and gault soils.

The available plant food is about normal in sample 39, but is rather high in samples 13 and 19 which are both used for market-gardening.

4. Glacial Series.

There is only one soil formation of this series, which may be named the glacial gravel soil formation. There are slight differences in texture and properties in the soils occurring on this formation but, as was previously explained, these are not sufficient to demand a sub-division.

For convenience in describing the formation it may be divided into two groups. (*a*) The Blunham glacial gravel area almost entirely devoted to market-garden crops; (*b*) isolated areas occurring as thin cappings on boulder clay, generally held by large farmers in conjunction with heavier land.

The Blunham area is of considerable extent. The soil is heavier in texture than any of the valley gravel formations and contains fewer stones, which are generally smooth with flat surfaces. The soil is a cool good working loam very suitable for peas, runner beans, brussels sprouts, late potatoes, onions, marrows and small seeds. The soil is not cropped quite so heavily as the valley gravel soil formations. The owner usually has to be satisfied with one crop a year but in some cases early peas are followed by brussels sprouts, or failing this, by spring cabbages. The soil is, as a rule, not so heavily manured as the green-sand or valley gravel soil formations, the land being dunged only once in two years.

In the case of the smaller areas of glacial gravel, occupied by larger farmers, one finds that they are following the market-gardening practice, either sub-letting their best fields to the market-gardener, or using them themselves for market-garden crops.

Late potatoes, brussels sprouts, onions, parsley and strawberries all flourish exceedingly on these rich glacial areas, while cereal crops and roots give very large yields. Potatoes with very indifferent treatment average 8 tons; onions average 8–12 tons, depending on the season. Very high yields of wheat are frequently obtainable, as high as 50 bushels to the acre being the yield in some years. The soil is so good that three cereal crops are often taken consecutively, each yielding very well. Wheat would average out at about 5 quarters and oats 10 quarters per acre. Strawberries too succeed particularly well and frequently give over 2 tons of fruit per acre.

Composition. The glacial soils are loams containing 8·5–9 per cent. stones and fine gravel, 40–50 per cent. sand fractions, 15–19 per cent. clay fraction. They are well supplied with calcium carbonate and potash. The phosphoric acid in sample 53, from one of the small areas, is very high ·47 per cent., while the available phosphate is outstandingly so for a soil which is not very heavily manured. The sample is somewhat low in available potash and probably would benefit by dressings of potash manures, particularly for market-garden crops. Sample 51 from the Blunham district contains available plant food to an extent only slightly above normal.

5. Brick Earths.

The material of this formation, laid down by rivers of an early period, is extremely uniform throughout the district, and therefore constitutes only one soil formation. The topsoil is a brown heavy loam, resembling the glacial soil formation very closely in texture, but containing fewer stones and gravel. The subsoil to a depth of several feet is characterized by a large percentage of rounded pieces of chalk, together with some fine gravel. The soil is used extensively for such crops as late potatoes, brussels sprouts, onions, parsnips, mangels and to some extent cereals. Only one crop a year is taken off this soil formation and consequently the land is not very heavily manured: 25–30 tons of dung once in three years seems to be the usual dressing.

Brussels sprouts or late potatoes usually receive the manure, while the following crops, onions and parsnips, are often dressed with soot. Malt dust is frequently used for onions on this formation, and is held in high esteem. There is no definite system of rotation of crops on this soil formation, but care is taken not to put the same crop on the land too frequently.

Composition. The brick earth soil formation is probably derived from material re-sorted from boulder clay. This being so, one would naturally expect a rather high content of calcium carbonate and potash and a somewhat low percentage of phosphoric acid. Chemical analysis reveals this in a marked manner, the only exception being the low percentage of calcium carbonate in the topsoil, sample 23. All other figures in the chemical analyses are strikingly uniform in both samples. The available plant food is about normal for the soils on this formation. Sample 29 which has till recently been in woodland contains rather a specially high percentage of nitrogen and available phosphoric acid.

6. Boulder Clay Series.

(*a*) *Pure boulder clay soil formation.*

This formation is characteristic of much of the higher ground in the district which is largely occupied by pasture, woodland, and mixed farming. In some places the pasture is extremely poor and is slowly going back into scrub. This land has at some period been quite largely used for cereal crops, for numerous fields can be seen laid in baulks. It is a fairly heavy clay soil but the high percentage of chalk, stones and fine gravel, added to the fact of better natural drainage, makes its cultivation easier than the pure gault or Oxford clay soil formations. The arable land of this soil formation is used for cereals, horse beans, mangels, mangel seed and clover. Brussels sprouts can be grown of good quality, and in places where the soil is a little deeper late potatoes and onions do moderately well.

The usual treatment of the land is somewhat as follows. Horse beans (15 tons dung), wheat, oats without manure, potatoes (if the soil is deep enough) (20 tons dung). Sometimes soot is used alone for potatoes without dung. Needless to say the crop in these cases is not very large. Clover seed is introduced occasionally into the above rotation. Clover, sainfoin and lucerne, where grown, do well on this soil formation, but cereal crops thrash rather lightly.

Composition. This formation is characterized by the rather high but constant content of clay, 23·6 per cent., a high content of calcium carbonate, 4·8 per cent. (average) and a low content of phosphoric acid, ·15 per cent. (average). The available potash is usually about normal but the phosphoric acid is invariably extremely low. One sample taken from small-holding land but recently acquired by a parish council for small market-gardeners contained an abnormally low content, ·001 per cent. of available phosphoric acid.

Sample 37 is an example of a deeper soil, resulting from local drift which is very heavily manured for potatoes, onions and parsnips.

The pure boulder clay soil formation is one which requires scientific treatment. Basic slag has wrought wonders at Croydon in the improvement of poor pasture, and phosphatic dressings are needed on this formation for nearly every crop.

(*b*) *Clay loam formation* (*alluvial on boulder clay*).

This formation occupies a small area on the right-hand side of the Ivel near Langford. It possesses a texture considerably lighter than the pure boulder clay soil formation and is therefore used extensively

for market-garden crops. Onions, parsley, parsnips, brussels sprouts and late potatoes are the principal market-garden crops, but mangel seed, horse beans, cereals and clover are also grown.

The treatment adopted by the market-gardeners for this soil is very similar to that in practice on the brick earths soil formation. Twenty tons of dung are used for potatoes or brussels sprouts and during the following two years soot and malt dust are used for parsnips and onions. The average yield of crops is very similar to the yields on the brick earths soil formation.

Composition. This formation contains a higher percentage of stones and coarser particles than the pure clay formation just considered. The soil is well supplied with calcium carbonate and the available plant food, particularly phosphates, is very much higher than that of the pure boulder clay soils.

(*c*) *Sandy loam soil formation* (*boulder clay on greensand*).

This formation occurs in the district only in two small areas but its characteristics are so different from true boulder clay that it must be designated as a distinct soil formation. This formation only occurs where the boulder clay covering the greensand forms a thin capping which intermixed with the sand results in a loamy soil. The texture of this soil formation varies even on the small areas mapped, owing to varying thickness in the capping of boulder clay. It resembles the redland soil formation in its characteristics and possesses the same property of going steely if caught wet with a hot sun.

This soil formation is mainly used for mixed farming but a small area of market-garden crops is grown. Brussels sprouts and late potatoes are the most important of these crops. Mangels, kohlrabi, barley and oats all do fairly well on this soil formation.

Composition. The only sample taken was from the more sandy part of this formation, since it was only on the more sandy parts that market-garden crops were grown. The sample is obviously a mixture of boulder clay and greensand and its properties are intermediate. The calcium carbonate is, however, very low, resembling the brown sand soil formation closely in this respect.

7. Valley Gravel Series.

(*a*) *Old brown soil formation.*

This soil formation derives its name from the extensive valley gravel deposits at higher levels on either side of the Ivel, in the neighbourhood of Biggleswade and Stanford. These gravels were evidently

laid down by a much larger river which probably flowed through greensand country from Flitwick to Shefford. The characteristic colour of these deposits, especially the extensive area from Broom to Stanford, is brown, hence the name "old brown" was applied to it to distinguish it from the more recent dark soil formation at a lower level.

It was found that the remaining gravel soils of the district, with the exception of a small area, which will be described later, could be referred to either one or the other of these two soil formations. It was found, however, convenient when giving the analyses of the gravel soils in the Appendix to group the samples together according to the localities from which they were taken. Thus any small variation due to local causes would be revealed. The area which has been referred to as an exception will be discussed later under the heading "Heavy brown soil formation."

The old brown soil formation is of such great extent and its areas are so widely separated that it is only to be expected that local causes will produce some slight variations in texture in different localities. There is, however, such a great resemblance in general characteristics that all the areas have been included as one soil formation. In order, however, to describe fully its properties and the effect of local conditions it has been subdivided into the following areas:

(1) Biggleswade Plateau.
(2) Stanford-Broom Plateau.
(3) Biggleswade Common Plain.
(4) Ouse Brown Gravels.

The Biggleswade plateau on the east side of the London Road resembles the Stanford-Broom plateau very closely in mineral structure and texture, but it has been greatly improved by heavy manuring with London dung. There is easy access to the Biggleswade railway station and evidently it has been under market-garden culture for a considerable number of years. The organic matter has been very notably increased by this heavy manuring and this makes it far more suitable for the growth of such crops as carrots and parsnips than it otherwise would be.

The Stanford-Broom plateau has been taken up by market-gardeners only in comparatively recent years and, owing to the distance from any railway station, the quantity of dung applied is very much less than in the previous case. It also has the disadvantage of a slightly increased percentage of stones and fine gravel, in one sample these fractions being 10 per cent. higher than the average for the Biggleswade soils. Owing to the small percentage of organic matter the soil on the Stanford-

Broom plateau is apt to form a thin hard cake on the surface. This makes the soil very unsuitable for such crops as carrots and parsnips, because it would be impossible to get a good "stand" of seedlings.

The Biggleswade Common plain and the Ouse gravels resemble the Stanford-Broom plateau very closely and in both cases the texture is not so good as on the Biggleswade plateau. The soil on the Biggleswade Common plain is rather more uniform in texture than the Stanford-Broom plateau. This is due to a wash of greensand material from the neighbouring escarpment. The subsoil shows just as much stones as the Biggleswade plateau soils, showing that the wash is purely a surface one. The agricultural treatment of this area is precisely similar to that of the Stanford-Broom plateau and mechanical or chemical analysis reveals an almost identical composition. The Ouse gravel soils are very similar in colour and properties to the soils of the Stanford-Broom plateau. In places, however, the underlying gravel beds come very near to the surface and make market-gardening a precarious occupation in dry seasons. Sample 65 is an instance of this, but sample 57 perhaps more adequately represents the Ouse gravel soils. This sample contains only 10 per cent. of stones which is very similar to the average content of the old brown soil formation.

The old brown soil formation taken as a whole is associated with the following market-garden crops: late potatoes, brussels sprouts, early potatoes, green peas and spring cabbages. Smaller quantities of runner beans, onions, parsley and parsnips are also grown on this formation. A considerable acreage of the formation is farmed, mangel seed, cereals and clover being the principal crops.

The large owners on this formation are gradually introducing market-garden crops in place of ordinary farm crops. They invariably winter a number of cattle in order to make farmyard manure for the hungry soil. In many cases little profit is made on the animals, but a supply of farmyard manure on the land even outweighs a small deficit on the animals.

As a rule these farmers aim at having one big crop a year rather than two small ones. The land is hardly in good enough "heart" to grow more than one good crop a year, but early potatoes followed by brussels sprouts is not uncommon. Early peas followed by spring cabbages and then an autumn crop, making three crops in two years, are also seen. The following example illustrates the rotation usually adopted by the larger owners on this soil formation: Potatoes (manured 20 tons farmyard manure). Brussels sprouts (manured 1 cwt. nitrate

of soda and 1 cwt. common salt). Oats without manure. Clover and rye or wheat. The average yield is 36 bushels of wheat and 5–6 quarters of oats to the acre.

The smaller market-gardeners on the Stanford-Broom plateau find it very difficult to obtain London dung and consequently rely greatly on soot, with poor results. Artificial manures are coming slowly into use, owing to this difficulty in obtaining dung, and one or two market-gardeners using them, it is true without much science, are nevertheless obtaining larger crops than their neighbours. The smaller market-gardeners appear to have no definite system of rotation of crops. They grow potatoes and brussels sprouts with an occasional crop of peas and cereals.

There is considerable rivalry between the Biggleswade and Potton market-gardeners in putting their crops first on the market. The Potton market-gardeners on the brown sand formation usually manage to place early potatoes on the market almost a fortnight ahead of the Biggleswade gardeners. This is due to a slightly heavier soil, in the case of the Biggleswade plateau, which retains the water to such an extent as to make this difference in earliness between the two soils.

The following analyses show the water content of the Biggleswade plateau and the brown sand formation at two different periods of the year. The samples were taken from soils on the same plateau at about corresponding altitudes.

	Depth of Sample	Greensand brown sand formation	Old brown soil formation (Biggleswade plateau)
Sampled	0 –9″	15·0 per cent. water	16·9 per cent. water
January, 1913.	9″–18″	12·8	12·9
	18″–27″	10·6	12·4
Sampled	0 –9″	12·0 per cent. water	14·8 per cent. water
April 24th, 1913.	9″–18″	11·2	12·9
	18″–27″	9·1	12·1

Composition. Mechanical and chemical analysis reveals a striking uniformity throughout all the samples of the old brown soil formation. They are all coarse gravel sands containing rather less coarse sand and more clay than the greensand brown sand formation. The content of potash and phosphoric acid is very similar to that found in the brown greensand soil formation. The old brown formation is largely derived from greensand material and this accounts for the close resemblance in the percentages of these ingredients. The soils of this formation are very deficient in calcium carbonate. The available phosphoric is usually high, but the percentage of available potash tends

to be low, particularly on the Stanford-Broom plateau. Sample 65 from the Ouse brown gravels contains very high percentages of available potash and phosphoric acid. This has probably largely been added in manures, for if the available content in samples 57 and 65 be subtracted from the total content of these ingredients, identical percentages for phosphoric acid and potash are obtained in both cases.

(*b*) *Heavy brown soil formation.*

This formation was laid down about the same time as the old brown formation, but differs from it in containing nearly 10 per cent. more of the two finer fractions, clay and fine silt. It is situated on the western edge of the old brown formation and runs from a little north of Southill to Upper Caldecote.

The crops associated with this formation are early potatoes, late potatoes, peas, spring cabbages, mangel seed, onions, cauliflowers, brussels sprouts and cereals. Mangel seed, peas and spring cabbages seem to be particularly suited to this soil. The farming practice on this formation is very similar to that used on the old brown formation and therefore need not be repeated.

Composition. Chemical analysis shows that this soil formation contains a much higher percentage of mineral salts and calcium carbonate than the old brown formation. The only exception to this is phosphoric acid which is rather low.

(*c*) *New dark soil formation.*

This soil formation is characterized by its dark colour and a more loamy texture than the old brown soil formation. It is more recent in age and the underlying gravels do not come so near to the surface. This formation has probably resulted from the mixture of material brought down by the tributaries of the Ivel, which join the main stream in the vicinity of Langford. The following analyses show the composition of sludges taken from the river bed of the Hiz and the main river.

	(*a*) Clifton-Shefford Main Stream	(*b*) Hiz
Moisture	·97 per cent.	2·57 per cent.
Org. matter	4·15	19·2
Nitrogen	·136	·84
Calcium carb.	3·25	34·6
Insol. residue	85·96	32·81
K_2O	·17	·50
P_2O_5	·18	·74
Fe_2O_3, Al_2O_3	5·46	9·67
CaO	2·04	18·95
MgO	·17	·74

The Clifton-Shefford branch is the main stream which flows continuously over greensand country from above Flitwick to Shefford. The sludge from this stream consists to a large extent of fine sand and coarse silt particles. It is comparatively low in calcium carbonate, potash, organic matter and all mineral salts. The Hiz tributary which at one time must have been very much larger flows over gault and chalk formations. The sludge from this stream is extraordinarily rich in calcium carbonate, organic matter, potash and phosphates. It contains a large percentage of the finer fractions such as clay and fine silt. Evidently it was the mixture of the material of these two streams which has produced the fine textured and fertile soils of the new dark soil formation. This soil formation is entirely devoted to market-gardening and probably this is the soil which was so famous for onions early in the nineteenth century. The soil in the neighbourhood of Biggleswade and Sandy has been devoted to market-gardening for centuries[1].

The soil on this formation is a fairly cool light loam with sufficient of the finer particles to prevent it from drying out in hot seasons. It is, however, underlain by gravel, at some depth below the surface and consequently the soil is well drained. Brussels sprouts, early and late potatoes, onions, carrots, parsnips, spring cabbages, parsley, peas and runner beans are all grown on this soil formation. It is the custom on this soil to grow three crops in two years. Early potatoes are frequently grown as a half crop with brussels sprouts or runner beans. Early peas are sometimes followed by brussels sprouts, but more frequently by spring cabbages. A main crop will usually follow on the land during the next year. Parsley is always associated with onions or carrots and is never grown as a separate crop.

The new dark soil formation is the most productive of all the soils used for market-garden crops. The land is extremely well manured with London dung and soot, but at present the quantity of artificial manure used is very small, with the exception of a top dressing of 1 cwt. nitrate of soda and 1 cwt. of common salt for forcing crops.

The crops on this soil formation are invariably much better in appearance and yield than those on the old brown soil formation. The following would be the average yields of the chief crops in fairly good seasons: Parsnips 16–20 tons, onions 10–14 tons, potatoes 8–10 tons, early potatoes (half crop) $3\frac{1}{2}$–5 tons.

[1] Batchelor, *loc. cit.*

Composition. The texture of this formation is rather more sandy in the neighbourhood of Langford and Eynesbury, but otherwise is comparatively uniform over its whole extent. The soil is usually well supplied with calcium carbonate, while the percentage of organic matter and potash is invariably higher than that of the old brown formation. The available plant food is very high on all the soils which have been used for market-garden culture, but even soils in pasture show a high content of available phosphoric acid (·059 per cent.).

PART III.

Relation of Crops to Soil Formations.

Hall and Russell[1] have demonstrated that by plotting the parish returns of a crop by means of dots on the areas of the various soils of each parish it was possible to bring out certain relationships between crop and soil, when the crop map thus constructed was compared with the geological map of the same area. Each dot represented a certain number of acres of some crop and the density of dots on the crop map revealed areas which were adapted to the growth of this crop. Thus they were able to show that hops and potatoes were each associated with certain types of soil.

This method appears to meet with considerable success where the soil occurring in a number of adjoining parishes is uniform over the whole area, but where a number of soil formations are to be found in one parish or adjoining parishes it is obvious that little relationship can be shown to exist by indiscriminate application of this method. Thus the relationship might not be brought out if the parish returns for a crop were to be dotted evenly over the whole parish area, irrespective of the fact that the crop may only occur on one of the several soil formations.

In the market-garden district of Biggleswade, the writer found many soil formations with distinct characteristics occurring in one parish. Any method of plotting the acreage of a crop indiscriminately over the parish area would thus have been useless for showing the real distribution of crops. Two maps, Nos. 5 and 6, have been constructed to show the result obtained by this method. Maps Nos. 7 and 8 have been made by dotting the acreage of the same crops over the area of the soil formation on which they occur. A comparison of the two sets

[1] Hall and Russell, *Agriculture and Soils of Kent, Surrey and Sussex.* Published by the Board of Agriculture and Fisheries, 1911.

of maps will reveal a great difference in the effect produced by the two methods of construction.

The details of the method used by the writer were as follows: The acreage of each crop on every soil formation was measured up. The acreage, choosing some suitable unit, was then dotted on the areas of a soil formation, which carried that crop. The 6 inch Ordnance Survey maps, which show the fields, were used in obtaining crop statistics. The crops on each field were measured up and the total acreage of each crop was worked out for each soil formation on which it was found to be growing on every sheet of the 6 inch map. The figures were then plotted separately for each 6 inch sheet on an outline map of the soil formations reduced to a one inch scale, and it was then found that certain soil formations were markedly associated with some particular crop.

The construction of these maps has involved a tremendous amount of labour, for the acreage of every crop on an area of nearly 100 square miles had to be estimated and then tabulated under the various soil formations with which they were associated. When it is borne in mind that the market-gardener grows a variety of crops on a small acreage of ground, the labour involved in making crop returns and calculating acreages will easily be seen to be no small one. Reproductions of the crop maps which show the distribution of twenty-one crops over the various soil formations are shown in the Appendix. An inspection of these maps at once reveals soils which farmers have found by experience to be well suited to the growth of various market-garden crops.

In the following short summary of the relationships brought out by these maps between crop and soil it is proposed only to indicate those which are most striking. The presence of smaller quantities of a crop on any formation will not be mentioned, as these have already been dealt with in a general way when describing the soil formations. The following are the most striking relationships:

Map 9. White turnips associated with brown and dark greensand formations.

Map 10. Early potatoes associated with brown and dark greensand and valley gravel soil formations.

Map 11. Carrots associated with dark and brown greensand soils, and the new dark gravel soil formation. The brown greensand grows more late carrots than early ones.

Map 12. Onions; new dark gravel soil formation, wash on Oxford clay, wash on boulder clay, and glacial soil formations.

Map 13. Runner beans; dark greensand soil formation, glacial and new dark gravel soil formations.

Map 14. Parsley; glacial, new dark gravel, dark greensand and parts of the old brown gravel soil formations.

Map 15. Late potatoes; grown on every soil formation with the exception of the pure Oxford and gault clay soil formations. They are particularly associated with the old brown gravel, glacial, boulder clay with wash and brick earth soil formations.

Map 16. Brussels sprouts; very wide distribution. They are grown on all classes of soil with the exception of the pure Oxford and gault clay soil formations. They are best suited to the loams and heavy loams such as the new dark gravel, glacial, boulder clay with wash and brick earth soil formations. Brussels sprouts are not suited to the light soils which in this district are all deficient in calcium carbonate and consequently get very "sick" if this crop is grown at all frequently. They are apt to "break away" during a mild winter on the light soils and the quality of sprouts is not nearly so good as that on the heavier soil formations.

Map 17. Parsnips; very similar in distribution to onions. The new dark gravel and the boulder clay with wash soil formations are the best soils for this crop.

Map 18. Marrows; not very extensively grown but closely associated with the new dark gravel and glacial soil formations.

Map 19. Green peas; glacial and all valley gravel soil formations.

Map 20. Spring cabbages; new dark gravel, brick earth and heavy brown gravel soil formations.

Map 21. Cauliflowers; very little grown but associated with the old brown and heavy brown gravel soil formations.

Map 22. Mangel seed; heavier types of soil such as pure boulder clay, wash on Oxford clay, wash on boulder clay, glacial and heavy brown gravel soil formations.

Map 6. Horse beans; heaviest types of soil such as pure Oxford clay, pure boulder clay, pure gault clay soil formations.

Map 23. Roots; loams and heavy loams such as wash on Oxford clay and particularly with redland and boulder clay on greensand soil formations. (Mangels, swedes and kohlrabi are included under the name of roots.)

Map 24. Small seeds (onion, carrot, parsley, turnip seed); glacial, Oxford clay with wash and brick earth soil formations.

Map 25. Legumes (clover, sainfoin, lucerne); heavier types of soil, but also with the old brown gravel soil formation.

Map 26. Cereals; wide distribution, but heavier soils more closely associated with them than other soil formations.

Map 8. Pasture; alluvial, pure Oxford clay and pure boulder clay soil formations.

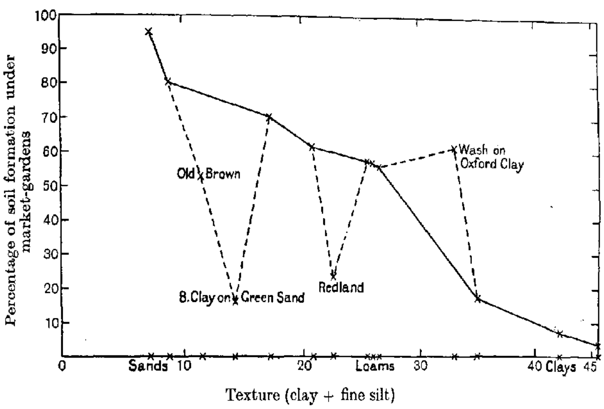
The following table has been prepared to show the extent to which the various soil formations are used for market-gardening. The percentages given are the percentages of arable land on each soil formation, occupied by (1) market-garden crops as a whole, (2) farm crops. For this purpose brussels sprouts and late potatoes have been considered as market-garden crops.

Series	Soil formation	Market-garden crops	Farm crops
Oxford clay	Pure	4·0	96·0
,,	Clay with wash	61·3	38·7
Greensand	Brown sands	80·0	20·0
,,	Dark sands	94·7	5·3
Gault	Pure	7·8	92·2
,,	Redland	23·6	76·4
Boulder clay	Pure	17·4	82·6
,,	With wash	57·0	43·1
,,	On greensand	16·3	83·7
Brick earths	Brick earths	57·5	42·5
Valley gravels	Old brown	52·7	47·3
,,	New dark	70·4	29·6
,,	Heavy brown	61·7	38·3
Glacial	Glacial	55·6	44·4

Below a graph has been drawn to show the relationship of market-gardening, as a whole, to the texture of the various soil formations. For this purpose the percentage of arable land devoted to market-gardening, on each soil formation, has been plotted against the percentage of clay and fine silt, together, in the soils of each formation. It will be noticed that the area devoted to market-gardening decreases fairly regularly with an increasing percentage of the finer particles. There are four exceptions which are shown by dotted lines on the graph. The redland and the boulder clay on greensand soil formations fall considerably below the main line. This is due to the fact that both these soil formations are difficult to cultivate owing to their property

of baking to steely lumps if caught by a hot sun. Both soil formations are rather small in area and perhaps it is hardly fair to include them in the diagram at all. The old brown gravel soil formation also falls below the main line curve, but, as previously explained, this formation is farmed to a large extent owing to the great difficulty in obtaining London dung so far away from any railway station.

The one exception to come above the main line is that of the Oxford clay with wash soil formation. This formation has been divided into allotments on account of the great demand for small holdings. The soil is not very suitable for most market-garden crops, but no other land is available for market-garden purposes.



The following table shows at a glance the proportion of each market-garden crop on each soil formation. The percentages given are percentages of the total arable land on each soil formation. These figures are not tabulated for the purpose of finding the soil formation most suited to a crop, because some of the soil formations are so small in area that it would hardly be safe to do this. The suitability of a crop to a soil formation is best divined by a study of the crop maps. This table does, however, bring out the various proportions of the different crops grown on any soil formation.

Table showing proportions of the various market-garden crops grown on each soil.

Figures give percentages of the total area occupied by each crop.

Crops	Oxford clay		Greensand		Gault		Boulder clay			Brick earth soils	Glacial soils	Valley gravels		
	Pure	With wash	Brown sands	Dark sands	Pure	Red-land	Pure	With wash	On green-sand			Old brown	Heavy brown	New dark
White turnips	—	—	23·3	32·3	—	3·4	—	—	2·3	—	—	·3	—	—
Cereals	72·5	25·0	14·2	5·3	63·5	60·0	62·5	31·9	62·3	40·0	36·5	35·2	26·2	22·5
Roots	—	4·0	4·8	—	5·9	9·7	1·9	2·5	11·4	·4	2·1	2·1	—	1·5
Brussels sprouts	1·9	23·5	18·8	16·0	4·9	11·0	8·3	21·3	2·5	16·9	19·8	20·5	6·3	21·2
Parsley	—	3·8	1·5	5·8	—	—	·5	1·5	—	2·1	7·8	3·4	3·4	5·5
Legumes	14·3	6·3	·9	—	14·4	6·7	10·3	4·7	8·4	1·3	4·2	6·7	—	2·3
Late potatoes	2·2	11·4	12·1	17·6	2·4	4·3	5·5	16·3	10·2	20·7	14·2	13·9	19·4	11·7
Early potatoes	—	2·8	61·0	66·5	—	·6	—	—	—	—	6·8	12·2	25·8	21·0
Cauliflowers	—	—	—	—	—	·8	—	—	—	—	—	1·5	8·7	·5
Summer cabbages	—	—	·2	—	—	·8	—	—	—	—	—	·9	—	1·2
Carrots	—	1·0	16·2	9·8	—	—	—	2·3	—	1·3	·8	1·1	—	8·3
Onions	—	7·7	·7	—	—	—	1·2	6·7	—	3·8	6·8	3·6	8·2	6·7
Runner beans	—	1·6	5·3	15·4	—	—	—	—	—	—	6·0	1·7	—	3·2
Beet	—	—	1·3	—	—	—	—	·6	—	—	—	—	—	·6
Parsnips	—	1·8	·8	—	—	—	·2	6·9	1·3	2·5	·5	3·1	2·6	5·2
Marrows	—	·7	·3	2·5	—	—	—	—	—	—	2·8	·7	2·3	2·0
Mangel seed	1·5	2·8	—	—	1·3	—	4·0	3·3	—	—	3·1	2·6	12·1	2·4
Horse beans	7·0	·5	—	—	5·3	—	3·9	·7	1·3	·8	1·6	·7	—	·9
Peas	—	1·6	·4	—	—	—	·3	—	—	—	4·0	5·9	16·8	2·9
Spring cabbages	—	1·7	4·8	·7	—	·6	—	·8	—	5·5	1·6	3·6	11·3	6·5
Small seed	—	2·4	—	—	·5	—	·5	—	—	2·2	3·6	1·3	—	·7
Asparagus	—	—	—	—	—	—	—	—	—	—	—	·3	—	1·2

SUMMARY.

The writer has demonstrated that the geological formations in this district give rise to a series of related soils which exhibit this relationship more closely in the mineral constituents than in the texture.

This series of soils may be usually divided into two or more soil formations having distinct characteristics which require different agricultural treatment. Mechanical and chemical analyses have been shown to define the soil formations very clearly, revealing striking uniformity among samples taken from the same soil formation and marking it off definitely from any other.

The writer has found the geology of the district to differ in several points from the unpublished draft sheets of the Geological Survey Department. Reasons have been given for any change on the geological map which the writer thinks desirable.

The soil formations have been described and their agricultural treatment correlated with the results of mechanical and chemical analyses.

Crop maps have been constructed showing the distribution of crops over the various soil formations and the relationships between crop and soil thus occurring have been described. The extent to which each soil formation is used for market-garden culture has also been shown.

The failure of the method of plotting the acreage of a crop indiscriminately over the parish area, in the Biggleswade market-garden district, has been demonstrated.

In all county soil surveys where there are extensive "quarternary" deposits, giving rise to variations in the soils overlying the geological formations, or where numerous geological formations outcrop within a small area, the writer would suggest that in addition to the ordinary soil survey usually conducted one or two small areas of about 30 square miles in country of typical variation should be minutely investigated in the manner described above in the present paper. If this is done, the author feels sure that many characteristics of soil and crop relationships will be brought out which otherwise would escape notice.

In conclusion, I have to thank Professor Wood for suggesting the subject for research and for his helpful advice during the progress of the work, and I wish also to thank Mr L. F. Newman who kindly placed at my disposal his long experience of soil survey work.

APPENDIX.

Oxford Clay Soils.

	Pure clay formation		Clay with wash			
Sample ...	69	70	55	63	64	67
Stones	1·8	1·0	1·5	2·2	2·7	1·4
Mechanical analysis:		subsoil			subsoil	
Fine gravel	1·9	1·8	1·1	1·7	1·0	·9
Coarse sand	14·8	13·7	23·3	20·0	21·0	21·7
Fine sand	9·8	8·4	15·7	16·4	15·1	18·0
Coarse silt	13·1	—	15·8	13·7	—	15·3
Fine silt	16·1	—	11·4	12·1	—	13·2
Clay	29·5	—	20·8	21·2	—	19·7
Moisture	5·01	—	3·1	3·5	—	2·9
Org. matter	8·29	—	6·1	8·4	—	5·6
$CaCO_3$	·12	—	·47	·70	—	·06
Total	98·6	—	97·8	97·7	—	97·3
Chemical analysis:						
Moisture	5·01	—	3·07	3·54	—	2·91
Org. matter	8·29	—	6·09	8·44	—	5·59
Nitrogen	·186	—	·182	·250	—	·152
Insol. residue	68·71	—	77·88	73·59	—	79·74
K_2O	1·18	—	·75	·76	—	·74
P_2O_5	·09	—	·12	·19	—	·08
Al_2O_3, Fe_2O_3	15·40	—	11·05	11·52	—	10·30
CaO	·65	—	·77	1·14	—	·51
MgO	·67	—	·47	·69	—	·46
Available 1 % citric acid:						
K_2O	·025	—	·031	·028	—	·021
P_2O_5	·002	—	·009	·051	—	·008

reensand Soils.

	Brown sands						Dark sands			
Sample ...	1	2	33	59	61	97	47*	71	77	99†
Stones	5·3	7·4	7·0	10·5	3·5	4·7	3·9	6·5	9·9	2·3
Mechanical analysis:		subsoil								
Fine gravel	11·3	8·8	3·6	9·8	4·5	—	2·5	7·6	5·0	1·0
Coarse sand	56·1	57·8	54·3	51·0	59·4	—	66·6	54·6	57·2	68·2
Fine sand	10·5	12·1	14·9	13·7	11·8	—	10·5	14·3	13·4	15·5
Coarse silt	7·5	6·3	8·3	9·9	8·4	—	4·3	9·8	6·6	3·1
Fine silt	3·5	4·1	5·8	3·4	5·0	—	3·9	1·7	3·6	3·1
Clay	4·7	5·7	6·4	2·9	3·5	—	4·0	3·9	5·4	3·7
Moisture	1·23	1·3	·90	1·8	1·2	—	1·4	1·4	1·2	·5
Org. matter	3·76	2·9	4·48	5·9	5·6	—	4·8	4·7	5·0	3·9
$CaCO_3$	·06	—	·07	·07	·09	·065	·10	·08	·09	·35
Total	98·65	99·0	98·7	98·5	99·5	—	98·1	98·1	97·5	99·35
Chemical analysis:										
Moisture	1·23	1·30	·90	1·77	1·16	·83	1·35	1·42	1·15	·55
Org. matter	3·76	2·90	4·48	5·92	5·57	7·87	4·82	4·68	5·00	3·90
Nitrogen	·101	·064	·127	·145	·162	·220	·145	·106	·122	·120
Insol. residue	83·70	83·70	82·72	81·15	83·05	80·37	85·74	85·11	84·47	89·94
K_2O	·22	·24	·22	·25	·22	·22	·24	·13	·18	·23
P_2O_5	·27	·25	·26	·24	·29	·28	·43	·11	·19	·16
Al_2O_3, Fe_2O_3	10·71	11·38	11·05	10·28	9·34	11·87	7·02	8·70	8·79	4·70
CaO	·10	·10	·25	·24	·23	·19	·53	·08	·33	·32
MgO	·16	·16	·25	·19	·19	·21	·21	·12	·16	·14
Fe_2O_3	8·56	9·00	—	—	—	—	—	—	—	—
Available 1 % citric acid:										
K_2O	·017	—	·023	·058	—	·017	·022	·014	·019	·015
P_2O_5	·034	—	·036	·061	—	·011	·084	·012	·037	·042

* Soil from Sandy slopes.

† Soil from Flitwick.

Gault Clay Soils.

	Pure clay formation		Redland formation			
Sample ...	41	42	13	14	19	39
Stones	7·5	1·1	2·3	1·8	3·5	2·0
Mechanical analysis:		subsoil		subsoil		
Fine gravel	1·2	1·5	2·2	2·2	3·9	2·5
Coarse sand	15·3	13·4	29·9	24·2	40·9	34·4
Fine sand	12·8	11·4	12·6	12·2	15·4	23·3
Coarse silt	9·4	—	12·6	—	11·2	12·1
Fine silt	12·9	—	10·4	—	8·0	8·5
Clay	29·3	—	18·4	—	9·9	12·0
Moisture	4·50	—	3·20	—	2·24	1·50
Org. matter	7·80	—	6·74	—	6·04	4·36
$CaCO_3$	3·52	—	·09	—	·29	·05
Total	96·7	—	96·1	—	97·9	98·7
Chemical analysis:						
Moisture	4·50	—	3·20	—	2·24	1·50
Org. matter	7·80	—	6·74	—	6·04	4·36
Nitrogen	·217	—	·185	—	·168	·129
Insol. residue	65·40	—	76·33	—	81·02	82·96
K_2O	·97	—	·65	—	·43	·47
P_2O_5	·19	—	·21	—	·29	·16
Al_2O_3, Fe_2O_3	15·83	—	11·70	—	9·46	10·13
CaO	3·09	—	·52	—	·36	·35
MgO	·74	—	·50	—	·27	·36
Available 1 % citric acid:						
K_2O	·031	—	·026	—	·018	·022
P_2O_5	·014	—	·048	—	·061	·027

Boulder Clay Soils.

	Pure clay soil formation					
e ...	8	15	16	43	6	37
	4·8	3·4	5·8	4·7	—	2·9
alysis:			subsoil			
el	·7	1·9	1·4	1·8	—	1·2
nd	11·6	19·5	20·5	16·6	—	20·6
	14·6	11·5	13·5	16·6	—	13·0
;	10·7	9·9	—	13·8	—	14·4
	12·1	10·5	—	11·7	—	9·0
	24·9	23·5	—	22·5	—	22·6
	3·8	4·1	—	3·2	—	2·9
er	8·2	5·6	—	6·6	—	8·7
ırb.	7·38	7·38	—	2·15	—	2·31
	94·0	93·9	—	94·95	—	94·7
'sis:						
	3·80	4·10	—	3·20	—	2·87
er	8·20	5·6	—	6·56	—	8·70
	·225	·202	—	·207	—	·309
lue	65·18	66·22	—	71·07	—	70·72
	·84	·80	—	·83	—	·69
	·14	·16	—	·14	—	·13
O_3	12·87	13·49	—	13·18	—	13·26
	5·10	4·84	—	3·12	—	2·07
	·71	·55	—	·59	—	·45
citric						
	·028	·019	—	—	·026	·012
	·004	·006	—	—	·001	·024

Boulder Clay Soils.

	Alluvial wash with boulder clay formation			Boulder clay on greensand	
Sample	79	80	31	109	110
Stones	7·9	—	3·1	5·2	—
Mechanical analysis:		subsoil			subsoil
Fine gravel	1·8	2·9	—	2·9	3·4
Coarse sand	27·5	21·3	—	46·8	44·8
Fine sand	18·5	15·5	—	18·9	17·2
Coarse silt	10·4	—	—	9·7	—
Fine silt	7·9	—	—	5·6	—
Clay	17·9	—	—	8·7	—
Moisture	2·6	—	—	·9	—
Org. matter	6·99	—	—	5·0	—
Calcium carb.	3·15	—	2·92	·08	—
Total	96·74	—	—	98·6	—
Chemical analysis:					
Moisture	2·65	—	2·32	·90	—
Org. matter	6·99	—	5·40	5·01	—
Nitrogen	·203	—	·176	·147	—
Insol. residue	73·46	—	77·42	83·37	—
K_2O	·65	—	·70	·41	—
P_2O_5	·17	—	·14	·28	—
Al_2O_3, Fe_2O_3	11·87	—	10·19	9·50	—
CaO	2·40	—	2·42	·30	—
MgO	·44	—	·56	·30	—
Available 1 % citric acid:					
K_2O	·025	—	·022	—	—
P_2O_5	·046	—	·021	—	—

Glacial Soils.

Sample	51	52	53
Stones	5·1	8·4	6·4
Mechanical analysis:		subsoil	
Fine gravel	3·2	1·8	2·7
Coarse sand	27·7	29·8	23·3
Fine sand	22·3	21·4	17·9
Coarse silt	10·7	—	10·3
Fine silt	8·3	—	9·7
Clay	15·5	—	19·3
Moisture	2·7	—	3·7
Org. matter	6·2	—	6·05
Calcium carb.	·81	—	4·63
Total	97·4	—	97·6
Chemical analysis:			
Moisture	2·67	—	3·72
Org. matter	6·27	—	6·05
Nitrogen	·175	—	·200
Insol. residue	78·21	—	71·68
K_2O	·59	—	·76
P_2O_5	·21	—	·47
Al_2O_3, Fe_2O_3	10·23	—	11·46
CaO	1·08	—	3·47
MgO	·47	—	·57
Available 1 % citric acid:			
K_2O	·033	—	·013
P_2O_5	·024	—	·075

Brick Earth Soils.

Sample ...	23	29	30
Stones	2·5	2·4	5·3
Mechanical analysis:			subsoil
Fine gravel	1·6	1·8	2·8
Coarse sand	29·2	27·4	30·6
Fine sand	19·1	16·9	18·1
Coarse silt	15·9	11·6	11·1
Fine silt	9·4	11·2	8·7
Clay	14·9	15·4	15·5
Moisture	2·2	1·8	2·4
Org. matter	5·1	8·1	7·4
Calcium carb.	·12	1·47	—
Total	97·5	95·7	—
Chemical analysis:			
Moisture	2·25	1·82	2·42
Org. matter	5·08	8·10	7·40
Nitrogen	·165	·312	—
Insol. residue	81·39	76·52	76·48
K_2O	·50	·52	·54
P_2O_5	·12	·16	·14
Al_2O_3, Fe_2O_3	9·37	9·61	10·17
CaO	·61	1·78	2·24
MgO	·42	·45	·50
Available 1 % citric acid:			
K_2O	—	·013	—
P_2O_5	—	·033	—

ample ...	Old brown soil formation: Biggleswade plateau 89	90	107	108	Stanford-Broom plateau 21	87	81
nes in soil	10·7	11·4	8·9	8·3	20·2	9·8	8·6
„ in subsoil	—	—	—	—	22·0	15·5	7·5
ical analysis:		subsoil		subsoil			
e gravel	3·3	3·7	3·4	3·1	8·5	3·7	2·6
rse sand	46·6	46·5	50·1	47·2	48·3	44·4	52·4
e sand	19·6	20·0	18·8	20·3	14·3	20·3	17·6
rse silt	11·1	12·0	10·0	10·1	11·2	14·2	12·1
e silt	5·2	5·7	5·1	5·4	6·3	3·7	3·6
y	5·7	6·7	6·6	8·9	5·2	7·2	5·9
sture	1·4	·95	·60	·7	1·0	·36	1·1
. matter	5·1	3·25	4·3	3·0	3·7	3·6	3·5
ium carb.	·08	—	·03	—	·06	·19	·1
Total	98·1	98·8	98·9	98·7	98·6	97·65	98·9
l analysis:							
sture	1·45	·95	·60	·68	1·00	·36	1·10
. matter	5·08	3·25	4·26	3·0	3·71	3·58	3·47
rogen	·155	·096	·127	—	·117	·084	·097
l. residue	85·98	88·03	88·27	88·88	86·44	86·19	88·71
)	·27	·31	·27	·31	·21	·25	·21
$_5$	·24	·19	·18	·15	·26	·20	·22
$_3$, Fe_2O_3	6·67	6·60	6·20	6·80	8·31	7·95	6·21
)	·42	·36	·31	·25	·15	·49	·23
)	·23	·25	·26	·27	·26	·28	·19
e 1 % citric							
)	·036	—	—	—	·015	·014	·014
$_5$	·090	—	—	—	·059	·050	·067

Sample ...	Old brown soil formation: Biggleswade Common 35	49	Ouse brown gravels 57	65
Stones in soil	—	4·5	10·2	23·1
„ in subsoil	9·4	7·9	9·2	29·4
Mechanical analysis:				
Fine gravel	4·5	5·3	2·4	5·8
Coarse sand	44·9	47·5	34·4	46·9
Fine sand	19·7	14·6	25·8	15·6
Coarse silt	13·3	10·8	15·0	9·2
Fine silt	5·2	6·3	6·7	6·3
Clay	6·1	3·8	8·0	6·0
Moisture	1·10	2·07	1·6	1·5
Org. matter	3·65	8·11	4·2	5·9
$CaCO_3$	·04	·07	·04	·38
Total	98·5	98·55	98·1	97·6
Chemical analysis:				
Moisture	1·10	2·07	1·59	1·46
Org. matter	3·65	8·11	4·23	5·93
Nitrogen	·127	·308	·147	·166
Insol. residue	87·74	82·76	86·81	83·48
K_2O	·26	·23	·32	·36
P_2O_5	·25	·20	·13	·33
Al_2O_3, Fe_2O_3	7·05	6·28	6·62	7·95
CaO	·23	·21	·30	·69
MgO	·24	·24	·26	·28
Available 1 % citric acid:				
K_2O	·036	·016	·015	·048
P_2O_5	·059	·011	·010	·149

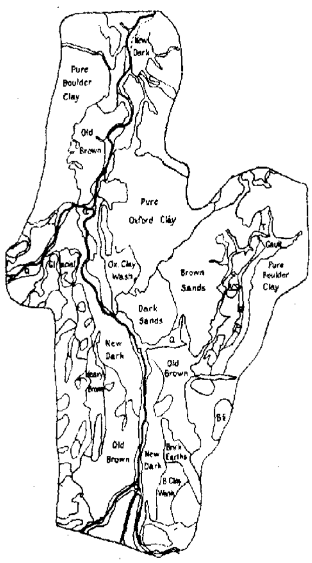
Valley Gravel Soils.

Sample ...	Heavy brown soil formation 105	106 subsoil
Stones	5·8	5·9
Mechanical analysis:		
Fine gravel	1·7	2·5
Coarse sand	34·1	34·5
Fine sand	21·8	20·0
Coarse silt	12·3	—
Fine silt	7·7	—
Clay	12·9	—
Moisture	·97	—
Org. matter	5·86	—
$CaCO_3$	·38	—
Total	97·7	—
Chemical analysis:		
Moisture	·97	—
Org. matter	5·86	—
Nitrogen	·165	—
Insol. residue	82·11	—
K_2O	·45	—
P_2O_5	·17	—
Al_2O_3, Fe_2O_3	9·06	—
CaO	·87	—
MgO	·42	—
Available 1 % citric acid:		
K_2O	—	—
P_2O_5	—	—

Valley Gravel Soils.

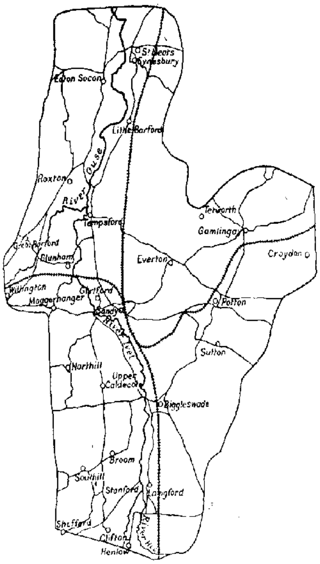
Sample ...	New dark soil formation 27	75	45	85	95
Stones in soil	11·1	12·2	2·9	12·5	—
,, in subsoil	13·1	13·0	—	12·2	—
Mechanical analysis:					
Fine gravel	1·9	3·9	1·2	3·7	—
Coarse sand	42·8	42·2	22·5	34·6	—
Fine sand	15·5	19·4	24·5	18·8	—
Coarse silt	10·5	10·2	18·1	12·6	—
Fine silt	7·0	5·5	8·9	6·7	—
Clay	10·3	8·9	11·3	10·7	—
Moisture	1·9	1·8	2·6	2·0	—
Org. matter	6·8	5·6	7·2	7·1	—
Calcium carb.	·43	·15	·86	·87	·16
Total	97·1	97·65	97·2	97·1	—
Chemical analysis:					
Moisture	1·95	1·80	2·62	2·02	·87
Org. matter	6·82	5·60	7·24	7·08	9·62
Nitrogen	·227	·181	·278	·238	·361
Insol. residue	81·25	83·74	78·46	79·89	80·00
K_2O	·43	·37	·38	·28	·33
P_2O_5	·37	·23	·22	·23	·27
Al_2O_3, Fe_2O_3	8·08	7·61	9·16	8·59	7·57
CaO	·94	·64	1·34	1·20	·87
MgO	·36	·33	·50	·29	·36
Available 1 % citric acid:					
K_2O	·024	·032	—	·021	·010
P_2O_5	·176	·092	—	·075	·059

Outline Map of Soil Formations.

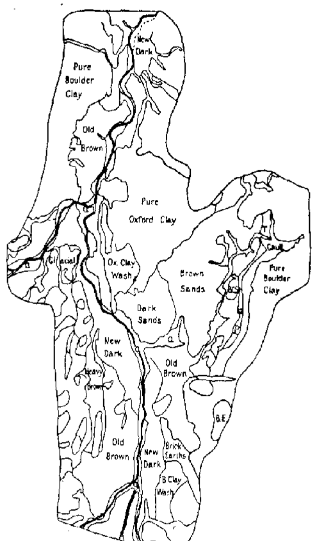


a = Alluvial. *rd.ld.* = Redland *B.C.S.* = Boulder clay or greensand.

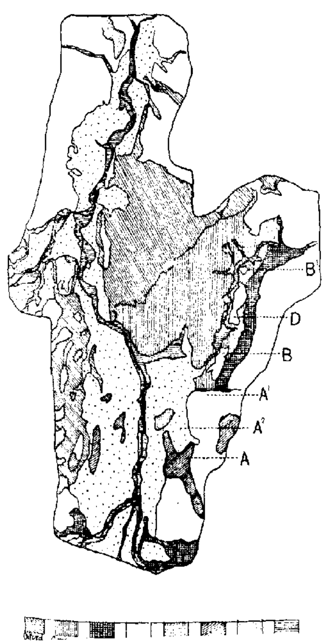
Outline Map of Soil Formations.

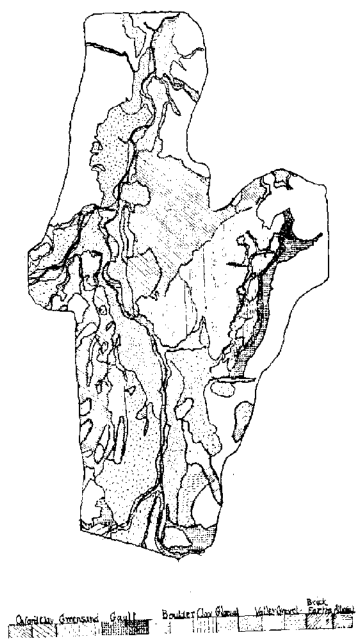


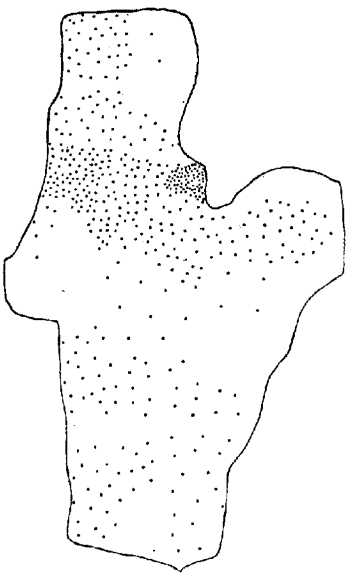
MAP 1 Topographical Map.



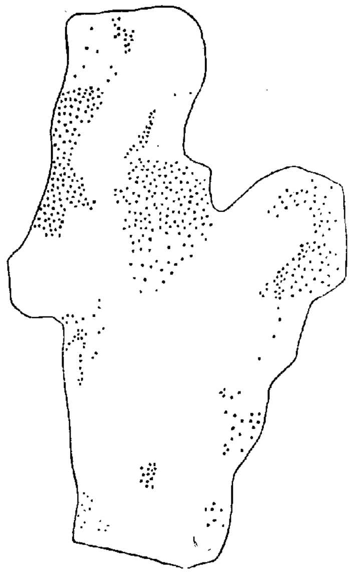
MAP 3. Outline Geological Map.
a = Alluvial. *rd.ld.* = Redland.
B.C.S. = Boulder clay or greensand.



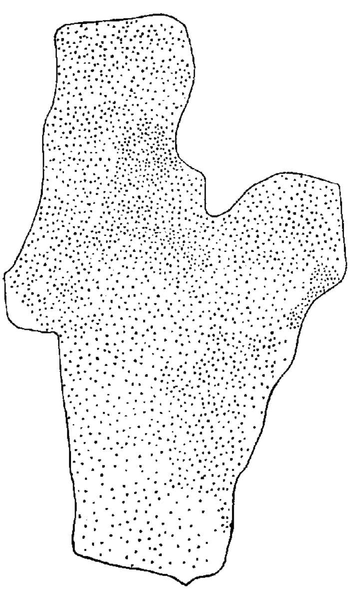




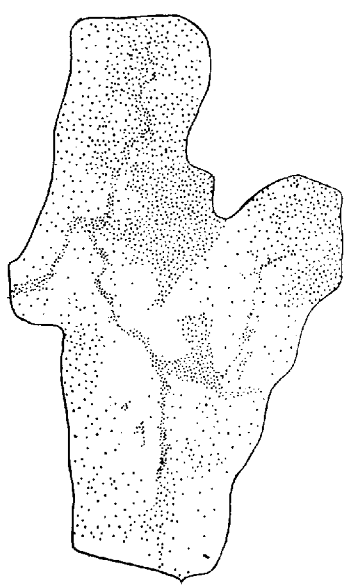
Map 5. Horse Beans. 1 dot—1 acre
Plotted on Parish area.



Map 6. Horse Beans. 1 dot—1 acre.
Plotted on Soil Formations.

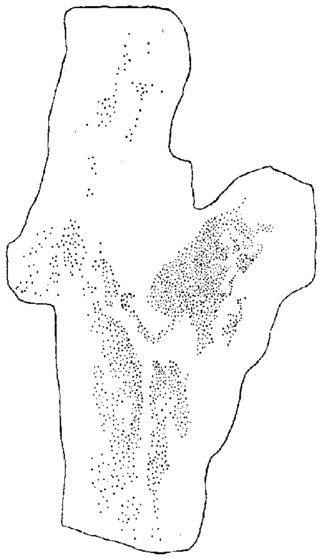


Map 7. Pasture. 1 dot—5 acres

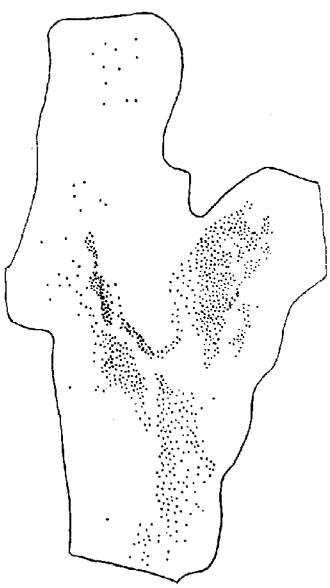


Map 8. Pasture. 1 dot—5 acres.

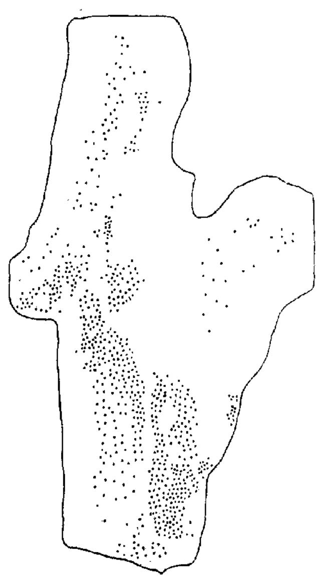
Map 9. White Turnips. 1 dot—1 acre.



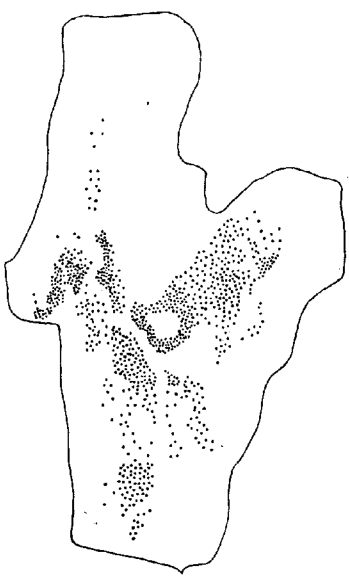
Map 10. Early Potatoes. 1 dot—2 acres.



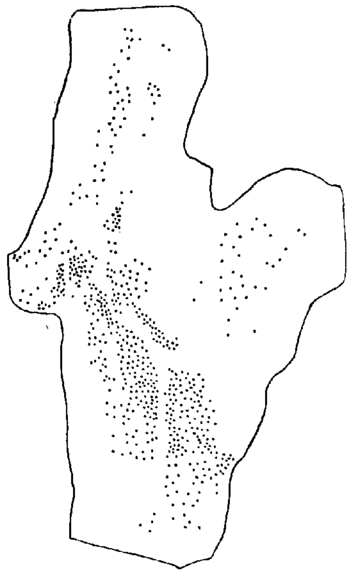
Map 11. [illegible]



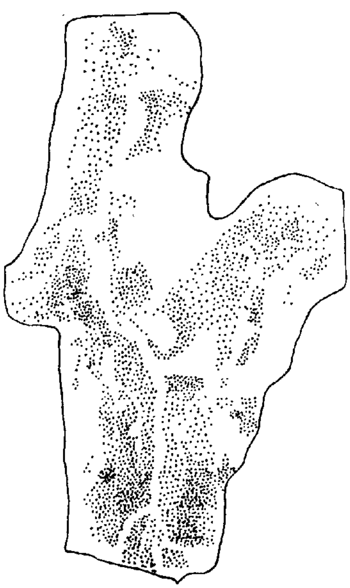
Map 12. Onions. 1 dot—1 acre.



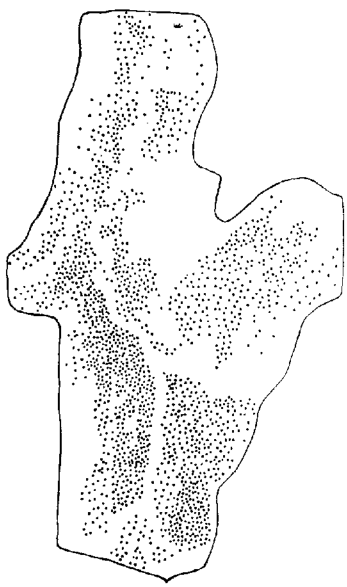
Map 13. Runner Beans. 1 dot—½ acre



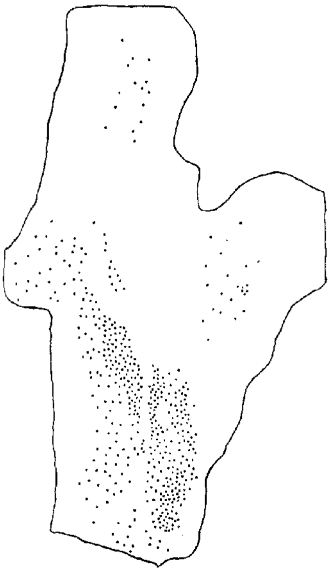
Map 14. Parsley. 1 dot—1 acre.



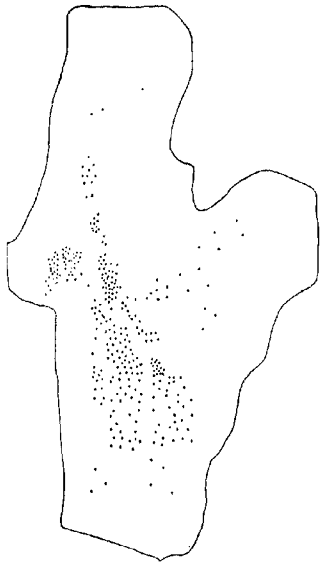
Map 15. Late Potatoes. 1 dot—1 acre.



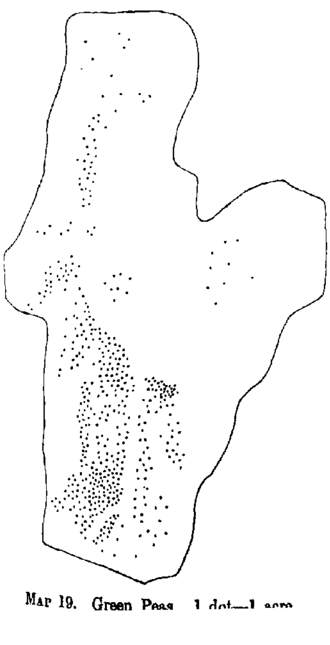
Map 16. Brussels Sprouts. 1 dot—2 acres.



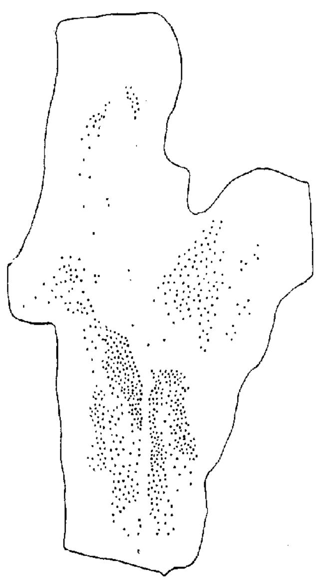
Map 17. Parsnips. 1 dot—1 acre.



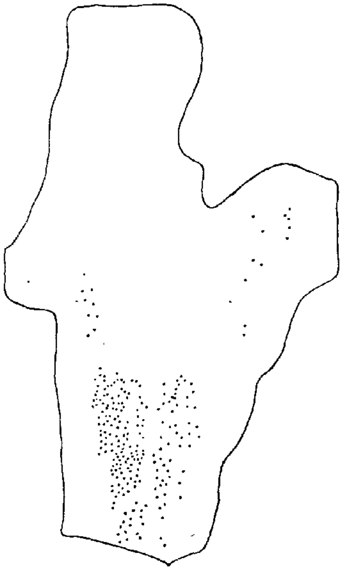
Map 18. Marrows. 1 dot—½ acre.



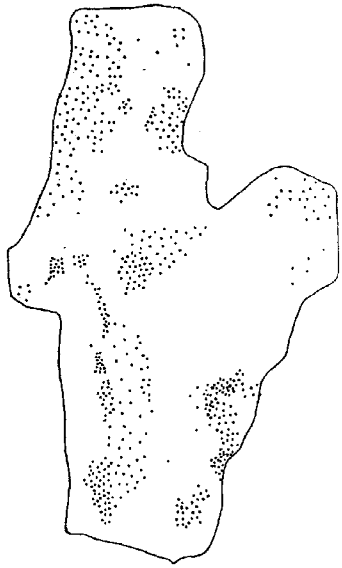
Map 19. Green Peas. 1 dot—1 acre.



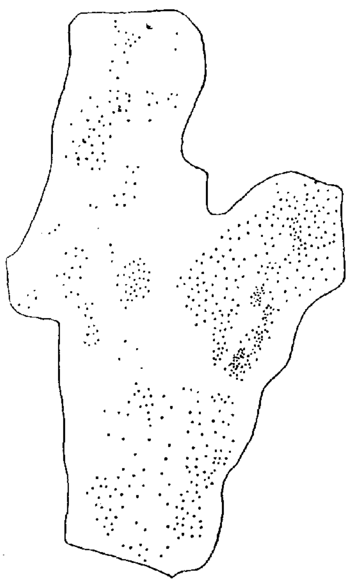
Map 20. Spring Cabbages. 1 dot—1 acre.



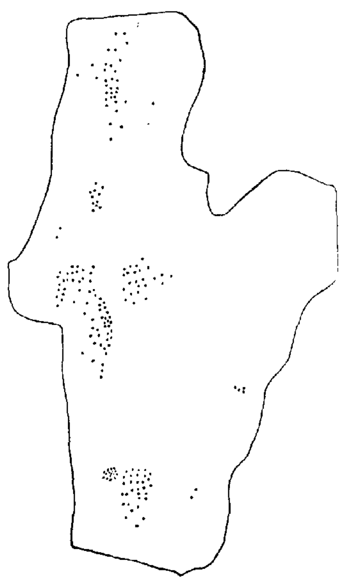
Map 21. Cauliflowers. 2 dots—1 acre.



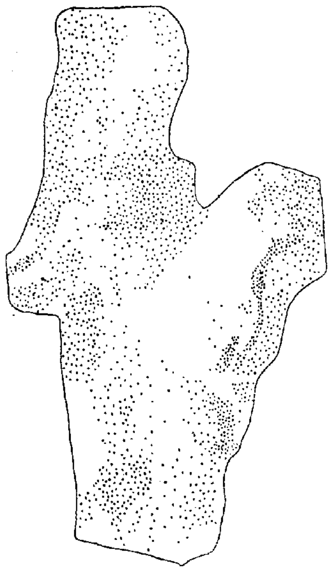
Map 22. Mangel Seed. 1 dot—1 acre.



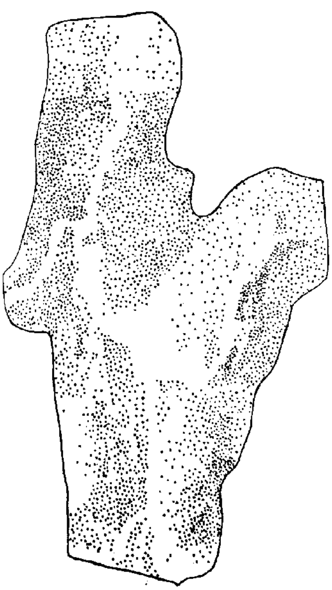
Map 23. Roots. 1 dot—1 acre.



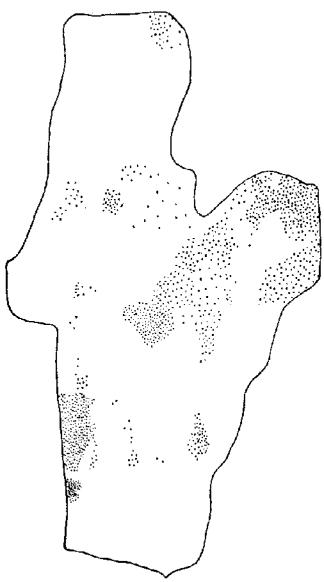
Map 24. Small Seeds—Carrot, Turnip, Onion, Parsley, Brussels Sprouts, Kohlrabi. 1 dot



MAP 25. Legumes. 1 dot—1 acre.



MAP 26. Cereals. 1 dot—3 acres



MAP 27. Parks and Plantations 1 dot—3 acres.

THE RELATION OF CERTAIN PHYSICAL CHARACTERISTICS OF THE WHEAT KERNEL TO MILLING QUALITY.

By C. H. BAILEY.

(Division of Agricultural Chemistry, Minnesota Agricultural Experiment Station, St Paul, Minn.)

The production of flour from wheat by the roller milling process is a series of mechanical operations which have as their final object the separation of the fibrous pericarp and the germ from the endosperm, and the reduction of the latter to a fine powder. The more exact the separation of these structures, the more desirable the process. In actual practice a quantitative separation is never obtained, since a plump wheat kernel may be from 82 to 85 per cent. endosperm[1], and yet only from 72 to 75 per cent. of the kernel is ordinarily recovered as flour. The other 10 or 12 per cent. adheres closely to the pericarp and germ fragments and is lost in the by-products or feeds. Since flour is the most valuable product of milling, it follows that those wheats which will yield the highest percentages of flour possess the greatest intrinsic value. The term "milling quality" is accordingly used by the writer in this paper to express the potential yield of edible flour when milled by the usual roller process.

When the same general system of milling is employed the relative yields of flour will depend, other thing being equal, upon the percentage of endosperm in the kernels. The quantitative determination of the proportion of the several kernel structures is difficult, since it involves the dissection of a sufficient number of kernels to furnish both a fair average sample and a quantity of material which can be satisfactorily weighed. There is a relation between the volume or displacement of the kernel and the proportion of endosperm, however, of which advantage may be taken. As shown by Brenchley[2], the pericarp and germ are

[1] Hunt. *Cereals in America*, p. 21, New York, 1908.

[2] Brenchley. *Ann. Bot.* **23**, 117–139, 1909.

formed largely during the early stages of the development of the kernel, and the endosperm structure is rapidly laid down during a comparatively short time preceding maturity. Any condition which interferes with the deposition of material in the endosperm during the later stages of kernel development reduces the quantity of potential flour material without reducing the amount of fibrous seedcoat in like proportions. A plump well-filled kernel accordingly yields more flour than does a shrivelled one. The comparison on the basis of kernel volume must be restricted to the same type or variety, since hereditary influences affecting the shape of the kernel, particularly its length, would affect the volume and weight without similarly affecting the ratio of endosperm to total weight.

To ascertain the relation between the kernel volume and the actual percentage of endosperm, samples were taken from a field of blue stem wheat at six stages of growth, beginning about ten days after flowering and at intervals of three days thereafter until the grain was nearly ripe enough to harvest. The kernels were at once removed from the heads, and the endosperm material dissected out of 100 kernels. The non-endosperm structures were dried to constant weight and 300 entire kernels were similarly dried. The difference in the weight of the kernels and of the non-endosperm material was regarded as the weight of the endosperm, since the latter was of such a sticky character that a loss was experienced in collecting it. The volume of the dried kernels was then determined by displacement in toluol. Table I shows the percentage of endosperm to increase fairly regularly from 62·6 per cent. when the kernels occupied a volume of 9·897 c.c. per 1000, to 81·7 per cent. when the kernel volume was 21·372 c.c. per 1000.

TABLE I. *Relation between the kernel volume and the weight and percentage of endosperm.*

Volume per 1000 kernels c.c.	Endosperm per 1000 kernels grams	Endosperm Per ct.
9·897	0·7950	62·6
12·317	1·1443	66·6
16·114	1·5682	69·8
17·871	1·7826	71·2
19·417	2·1275	76·9
21·372	2·4576	81·7

The volume of the kernel may vary widely in the same type or variety of wheat when grown under different conditions. Thus hard spring

wheat samples grown in Minnesota have been examined which displaced from 7·2 to 25·2 cubic centimetres per 1000 kernels. Greater extremes than these would doubtless be found in working with a larger number of samples. These variations are due to environmental influences, particularly those which affect the rate of photosynthesis just preceding the ripening of the plant. Soil moisture, humidity, sunshine, temperature, and winds are most potent in this regard. Severe rust and scab infections result in the production of shrivelled, light-weight kernels.

Similarly there are wide variations in the percentage of flour which can be produced from wheats of varying plumpness. In estimating the relative percentage of flour which can be milled from different samples of wheat, the kernel volume and the density are believed to be better indices than the weight per bushel. The latter is influenced not only by the actual volume of the kernels but by their relative length : width ratio, and other factors affecting the manner in which they pack together. While the relation of the two factors mentioned to milling yield is not exact in all cases, certain experiments which we have made show them to be of considerable value in estimating the quality of wheat from this standpoint.

TABLE II. *Physical characteristics of composite samples of northern spring wheat grades and the yield of flour obtained from them in milling.*

Lab. No.	Grade	Specific gravity	Volume per 1000 kernels c.c.	Flour yield Per ct.
C 835	No. 1 northern spring ...	1·4218	16·10	70·0
C 836	„ 2 „ „ ...	1·4112	14·31	69·1
C 837	„ 3 „ „ ...	1·4212	12·97	66·9
C 838	„ 4 „ „ ...	1·4238	10·50	65·2

Table II shows the results of one series of tests made to determine the relation of kernel volume to the percentage of total flour obtained in milling. A fairly regular decrease in flour yield was observed as the kernels decreased in size. The samples employed in this case were composite No. 1, No. 2, No. 3, and No. 4 northern spring wheat, representing the average of these grades in the Minnesota markets. Similar results were obtained in milling other wheat samples of varying plumpness. The milling tests were made in the experimental roller mill at this station. The method employed is described in Minnesota Agricultural Station Bulletins, Nos. 131 and 143. While the flour

yields obtained with this small equipment are not identical with those obtained by large merchant mills working on the same materials, they are comparative with each other if the experimental mill is properly handled.

The other two physical characteristics which bear the most definite relation to milling value are the density of the kernel, more particularly that of the endosperm, and the moisture content. The moisture content is considered as a physical rather than a chemical characteristic since it can be altered by purely physical means. An increase in moisture content above the normal results in increased losses through evaporation, as has been shown by the writer[1]. In addition, damp wheat presents certain mechanical difficulties in milling, owing to its soft character, which render more difficult the separation of the bran and endosperm. For these reasons, and because of the increased liability of spoilage through fermentation and heating, damp wheat is of less value to the miller than dry wheat.

The density of the endosperm of the wheat kernel is known to vary widely. These variations are commonly distinguished as "mealiness" in the case of the less dense, and "flintiness," or a "vitreous," "horny" or "corneous" condition in the case of the more dense. The light-coloured condition of the endosperm frequently met with in the hard red wheats is usually referred to as "yellow-berry"; when the entire kernel is not affected it is sometimes called "piebald." These variations in endosperm density have been the subject of numerous investigations. Nowacki[2] states that the difference in appearance of mealy and horny wheat kernels is due to the presence of a larger volume of air-spaces in the former. Hackel[3] (p. 26) says, "If the albuminoids so fill up the intervals between the starch grains that the latter seem to be imbedded in cement, the albumin appears translucent and the fruit is called corneous; but if the union is less intimate, there remain numerous small air-cavities and the albumin is opaque and the fruit is mealy. Both conditions may occur in the same species or variety (wheat) and they seem to be occasioned by differences in climate and soil. Corneous fruits are usually richer in albuminoids than mealy ones of the same species." Pagnoul[4] and Wollny[5] found that the specific gravity of

[1] Bailey. *Canadian Miller and Cerealist*, vol. VI. pp. 74–75, 1914

[2] Nowacki. *Untersuchungen über das Reifen des Getreides*, Halle, 1870.

[3] Hackel. *The True Grasses.* Translation by Lamson-Scribner and Southworth. New York, 1890.

[4] Pagnoul. *Ann. Agron.* vol. XIV. pp. 262–272, 1888.

[5] Wollny. *Forsch. a. d. Gebiete Agrikulturphysik.* vol. IX. pp. 207–216, 1886.

the wheat kernel increased with the nitrogen or protein content. Marek[1] states that in the samples examined by him a decrease in nitrogen content was accompanied by an increase in specific gravity. Kornicke and Werner[2] state that the constituents of the wheat kernel have the following specific gravity: starch, 1·53; sugar, 1·60; cellulose, 1·53; fats, 0·91–0·96; gluten, 1·297; ash, 2·50; air, 0·001293. They further state that the volume weight bears no relation to specific gravity or to protein content. Lloyd[3] determined the weight per 100 kernels, volume weight, and densities of wheats from different parts of the world and found Russian wheat to possess the lowest average weight per kernel, and Australian wheat the highest. Wheat grown in the United States and Canada had the highest average density or specific gravity, and that grown in England the lowest. Pammel and Stewart[4] found the specific gravity of wheat examined by them to range between 1·407 and 1·503. Lyon[5] states that wheat kernels having a high percentage of proteid material have a lower specific gravity. His data (p. 57) indicate that large kernels have a higher specific gravity than small kernels of the same variety. Cobb[6] observed that there are fewer large starch granules in wheats containing a low percentage of nitrogen. Lyon and Keyser[7] confirmed Cobb's observations, and also found that large and numerous vacuoles are associated in yellow-berry kernels. The difference in structure between horny and yellow-berry kernels was also accompanied by a difference in nitrogen, the yellow-berry kernels containing less nitrogen than the horny. Roberts[8] states that the presence of air vacuoles doubtless accounts for the lower specific gravity of yellow-berry kernels. He later[9] presented the results of a number of physical measurements of wheat kernels, including specific gravity. The samples examined by him ranged in specific gravity from 1·218 to 1·386. Willard and Swanson[10] determined the specific gravity and other factors of quality for Kansas, Minnesota, Tennessee, and Washington wheats. They state (p. 81) that there is a tendency for large kernels

[1] Marek. *Landw. Zeit. f. Westfalen u. Lippe*, p. 362, 1875.
[2] Kornicke and Werner. *Handbuch d. Getreidebaues*, Berlin, 1884.
[3] Lloyd. *Amer. Journ. Pharm.* vol. LXVI. pp. 413–419, 1894.
[4] Pammel and Stewart. *Iowa Exp. Sta. Bul.* No. 25, pp. 26–31, 1894.
[5] Lyon. *U.S. Bur. Plant Ind. Bul.* No. 78, 1905.
[6] Cobb. *Agr. Gaz. New South Wales*, vol. XV. p. 512, 1904.
[7] Lyon and Keyser. *Nebraska Exp. Sta. Bul.* No. 89, 1905.
[8] Roberts. *Kansas Exp. Sta. Bul.* No. 156, 1908.
[9] Roberts. *Kansas Exp. Sta. Bul.* No. 170, 1910.
[10] Willard and Swanson. *Kansas Exp. Sta. Bul.* No. 177, 1911.

to have the higher specific gravity, and further, that small, compact kernels have a higher specific gravity than the large (and presumably less compact) ones.

The methods previously employed for the determination of specific gravity did not appear in most instances to be wholly satisfactory. A new method was accordingly developed by the writer in collaboration with L. M. Thomas[1]. About 10 grams of wheat kernels, freed from dirt, weed-seeds, other grains, and broken kernels, are weighed on an analytical balance, and the exact weight recorded. The wheat is then placed in a 50 c.c. pycnometer, which is provided with a ground-in thermometer, side-tube, and over-flow cap. The grain is just covered with cool toluol, the side-tube plugged, and the neck of the pycnometer connected with pressure tubing to an aspirator. The air is then exhausted to free the mass of grain from air mechanically held in the brush and crease of the kernels. Unless this is done the air so held will materially reduce the apparent specific gravity. Moreover the quantity of air present and removed by aspiration varies, as it depends upon the shape and size of the kernels. In nine trials it ranged from 0·101 c.c. to 0·335 c.c. After the bubbles cease to rise through the toluol, air is slowly admitted, and the pycnometer is disconnected from the aspirator and completely filled with toluol at a temperature of about 18° C. The temperature is allowed to rise slowly to 20°, as shown by the thermometer in the pycnometer, the last drop on the side-tube is wiped off, and the over-flow cap set firmly in place. Pycnometer and contents are then weighed on the analytical balance. The exact capacity of the pycnometer and the specific gravity of the toluol must of course be known. The latter averages about 0·8665. The specific gravity of the wheat is calculated according to the following formula:

$$\text{specific gravity of wheat} = \frac{\text{specific gravity of toluol} \times \text{weight of wheat}}{\text{weight of displaced toluol}}.$$

From the weight of toluol displaced by the wheat its volume can be calculated and this figure divided by the number of kernels in the pycnometer gives the average volume per kernel. From the weight of wheat in the pycnometer the weight per 1000 kernels can also be calculated when the number of kernels is known.

These investigations have shown the kernel density to be dependent first upon the proportion of pericarp and germ to endosperm, and second upon the density of the endosperm. As a general rule the small kernels,

[1] Bailey and Thomas. *U.S. Bur. Plant Ind. Circular* No. 99, 1912

which have the larger proportion of bran and germ, also have the lower specific gravity. This is shown by Table III, which gives the specific gravity of a number of hard red spring wheat samples arranged according to their size or kernel volume. Deviations from the general rule exhibited by certain of these samples may be explained on the basis of their nitrogen content, as will be shown later. Thus C 783 in the first group has a specific gravity of 1·4083, which is somewhat above the average of similar samples so far as kernel volume is concerned. It contains 2·62 per cent. of nitrogen, however, which is considerably more than is found in the others in the group. Similarly the average specific gravity of the entire second group, in which the kernel volumes range between 12 and 14 c.c. per 1000, is probably somewhat high because of the higher average nitrogen content. The data indicate that the bran and germ tissues have a lower specific gravity than do the endosperm structures, which fact must be considered in evaluating wheats on the basis of specific gravity.

TABLE III. *Relation of specific gravity to kernel volume.*

Lab. No.	Specific gravity	Volume per 1000 kernels, c.c.	Nitrogen Per ct.
	Less than 12 c.c. per 1000 kernels.		
C 784	1·3895	7·21	2·30
C 789	1·3934	10·86	2·12
C 783	1·4083	10·97	2·62
C 795	1·3862	11·72	2·18
C 796	1·3607	11·78	2·16
Average	1·3876	10·51	2·28
	From 12 to 14 c.c. per 1000 kernels.		
C 782	1·4022	12·74	2·28
C 789	1·4016	13·75	2·54
C 791	1·4033	12·35	2·86
C 793	1·4099	12·98	2·39
Average	1·4042	12·95	2·52
	Over 14 c.c. per 1000 kernels.		
C 786	1·4101	14·48	2·07
C 790	1·4104	14·71	2·35
C 794	1·4233	15·83	2·44
C 792	1·4212	18·54	2·47
Average	1·4162	15·89	2·33

Practical flour millers have observed that in general the milling of the soft types of wheat by the roller process presents greater difficulties than does the milling of hard kinds of the same degree of plumpness.

The flour middlings, or endosperm particles, are more difficult to separate from the bran. Their subsequent reduction to flour between the smooth rolls is not accomplished as easily as when they were produced from harder kernels, owing to their tendency to flatten out or "flake," and lose their granular character before the reduction is complete. There is in consequence an increased loss of endosperm or floury material in the feeds or by-products. Increasing the length of the milling system aids somewhat in effecting a more complete separation but involves greater expense of operation.

TABLE IV. *Physical characteristics, flour yield, and nitrogen content of vitreous and mealy samples of hard red spring and hard red winter wheats.*

Lab. No.	Total nitrogen Per ct.	Volume per 1000 kernels c.c.	Specific gravity	Flour yield Per ct.
		Vitreous spring wheats.		
C 195	2·79	20·58	1·4185	71·2
C 317	2·29	22·94	1·4233	69·1
C 294	2·46	19·56	1·4180	69·6
C 321	2·30	20·94	1·4251	73·0
C 298	2·56	19·70	1·4184	72·3
Average	2·48	20·74	1·4207	71·0
		Mealy spring wheats.		
C 308	1·82	18·60	1·4106	70·6
C 338	1·92	24·17	1·3988	68·8
C 353	2·02	20·56	1·4015	69·7
C 372	1·89	22·98	1·4031	67·7
C 396	1·99	20·65	1·4174	69·6
Average	1·93	21·39	1·4063	69·3
		Vitreous winter wheats.		
C 263	2·31	18·63	1·4277	67·8
C 631	2·10	20·68	1·4262	72·7
C 567	2·25	21·45	1·4225	71·7
C 616	2·25	23·92	1·4129	71·7
C 673	2·42	23·97	1·4241	71·2
Average	2·27	21·73	1·4227	71·0
		Mealy winter wheats.		
C 239	1·62	23·10	1·4051	70·8
C 247	1·52	19·98	1·4109	69·9
C 249	1·66	20·82	1·4022	66·8
C 252	1·49	20·54	1·4101	64·7
C 260	1·63	21·77	1·4000	68·2
C 265	1·64	22·51	1·3990	66·9
C 289	1·64	21·59	1·3964	66·2
Average	1·60	21·47	1·4034	67·6

No exact information was available on the relation of kernel density to milling yield when the same general system of milling was followed in all cases. There were on file in this laboratory several hundred wheat samples which had been analysed, and milled in a 5-break and 8 to 11 reduction system. From these were selected at random twenty-two samples of both hard red spring and hard red winter (Turkey Red)

TABLE V. *Physical characteristics and nitrogen content of soft red winter wheats grown in the eastern United States.*

Lab. No.	Source	Specific gravity	Volume per 1000 kernels c.c.	Nitrogen Per ct.
	Less than 1·80 per cent. of nitrogen.			
C 727	St Mary's County, Maryland ...	1·3393	26·89	1·50
C 723	Talbot County, Maryland	1·3303	25·75	1·53
C 721	Northumberland County, Maryland	1·3401	26·02	1·58
C 725	Westmoreland County, Maryland ...	1·3432	27·75	1·60
C 722	St Mary's County, Maryland ...	1·3444	27·10	1·60
C 724	Queen Anne County, Maryland ...	1·3633	30·22	1·62
C 720	Talbot County, Maryland	1·3419	25·99	1·64
C 716	Dorchester and Caroline Co., Md.	1·3804	28·06	1·64
C 717	Queen Anne County, Maryland ...	1·3568	26·35	1·66
C 729	Washington, Indiana	1·3728	35·07	1·68
C 719	Queen Anne County, Maryland ...	1·3592	24·12	1·74
C 718	Queen Anne County, Maryland ...	1·3606	31·28	1·75
C 728	Washington, Indiana	1·3898	22·92	1·79
	Average	1·3556	27·50	1·64
	More than 1·80 per cent. of nitrogen.			
C 741	Lyndon, Ohio	1·3818	24·86	1·82
C 739	Washington, Indiana	1·3981	25·93	1·84
C 731	New Vienna, Indiana	1·3856	22·72	1·90
C 743	Arcanum, Ohio	1·4083	27·29	1·90
C 737	Thrifton, Ohio	1·4070	25·18	1·94
C 734	Xenia, Ohio	1·4019	22·09	1·98
C 732	Washington C. H., Ohio	1·4155	22·23	2·00
C 738	Elmora, Indiana	1·4025	23·87	2·00
C 730	Madison Mills, Illinois	1·3866	23·56	2·01
C 740	Chillicothe, Ohio	1·3900	22·97	2·04
C 733	Derby, Ohio	1·4106	24·42	2·11
C 736	Markelville, Indiana...	1·4084	24·18	2·14
C 735	McCords, Indiana	1·4014	24·82	2·18
	Average	1·3998	24·16	2·00
	Average of both groups	1·3777	25·83	1·82

wheat of approximately the same degree of plumpness, but varying in colour and hardness. The soft, mealy samples represented what is commonly termed "yellow-berry." The kernel volume and specific

gravity of these samples were then determined and the results of these tests, the flour yields, and the percentages of total nitrogen are shown in Table IV. The data are grouped according to type of wheat, i.e., winter or spring, and into two sub-groups in each case according to relative hardness. While there is some overlapping in the case of the flour yields from the vitreous and mealy samples, the general tendency was decidedly in the direction of larger flour yields from the vitreous grain. The relation between density or specific gravity and percentage of nitrogen is also marked, the samples having a lower specific gravity almost invariably having a low nitrogen content as well, when the comparison is restricted to kernels of about the same volume or plumpness.

For comparison with the hard wheats of the northern Great Plains area, a number of samples of soft red winter wheats grown in the eastern half of the United States were secured through representatives of the Office of Grain Standardization of the United States Department of Agriculture. The results of the tests of these samples are given in Table V. They are arranged in two groups, those having a nitrogen content of less than 1·80 per cent. being included in the first group, and those of 1·80 per cent. or over in the second group. These soft red wheats have a lower average specific gravity and nitrogen content than the hard wheats, although the average kernel volume is greater. The same relation between nitrogen content and specific gravity prevails here as did in the case of the hard wheats studied, viz. the higher the nitrogen content, the greater the specific gravity, as a general rule.

SUMMARY.

Kernel volume, because of its relation to the ratio of endosperm to non-endosperm structures, varies directly with the potential flour yield when comparisons are restricted to the same type or variety of wheat.

Accurate determination of kernel density must include the complete removal of all mechanically held air.

Large kernels, other things being equal, have a higher specific gravity than small kernels of the same variety, indicating the endosperm to have a higher specific gravity than the bran and germ.

Relative density of the endosperm is generally conceded to be dependent upon the proportion and size of the air vacuoles. Soft, light-coloured, yellow-berry kernels have a lower specific gravity than

hard, dark-coloured kernels of the same variety. The more dense the endosperm, other things being equal, the greater the ease of, and the more complete, the separation of endosperm from bran and germ in milling.

Wheat kernels of a high specific gravity have a higher nitrogen content as a usual thing than less dense kernels of the same relative size or volume.

Hard red wheats grown in the northern Great Plains area, while varying widely, have a higher average specific gravity than do the soft red winter wheats grown in the eastern half of the United States.

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SOME EXPERIMENTS ON THE HOUSE-FLY IN RELATION TO THE FARM MANURE HEAP.

By H. ELTRINGHAM, M.A., D.Sc.
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In the early part of the present year the suggestion was made to me by my friend Mr J. C. F. Fryer that I should carry out a series of experiments designed to test the fly-breeding capacity of the open farm manure heap as distinguished from heaps in close proximity to dwellings.

Of late years the danger of the fly pest has been made clear to the most unscientific of the public and in many directions determined efforts have been made to reduce the number of flies infesting houses, thus minimising not only the physical nuisance, but also a far more important factor, the danger entailed by the flies' power of carrying disease.

It is unnecessary here to set forth the proofs which have been obtained of the capacity of flies to convey bacteria, or the methods by which they distribute the organisms they carry and contain. Those who desire to learn the details of a somewhat unpleasant study should read Dr L. O. Howard's work, *The House-Fly—Disease Carrier*. There they will find the whole subject set forth in a manner which leaves the reader wondering which to admire more, the completeness of the work or the literary skill which can make so unsavoury a subject both readable and entertaining. Neither is this the place to summarise the excellent work carried out by many investigators amongst whom the names of Dr Graham Smith, Dr L. O. Howard, Dr C. Gordon Hewitt, Professor Maxwell Lefroy, Professor R. Newstead, and others, will immediately occur to those who are interested in these matters. Dr C. Gordon Hewitt's volume on the House-Fly is the standard work on the anatomy and life-history of the insect.

I have before me a list of over 100 authors of volumes and papers dealing with the subject. With so formidable an array of literature available it may be asked what further point remains to be elucidated. All are agreed that house-flies breed in almost any refuse and particularly in manure. So certain and universally accepted is this fact that it has induced an almost equally general converse belief that all manure breeds house-flies.

The object of my research has been to ascertain to what extent this latter hypothesis could be supported by actual experiment. I am indebted to Dr E. J. Russell, the Director of the Rothamsted Experimental Station, for providing every facility for carrying out the work under the most favourable conditions, and to the Board of Agriculture for a grant towards the personal and material expenses incurred.

I should like to take this opportunity of thanking all the members of the Staff of the Rothamsted Laboratory for their many kindnesses, and especially would I express my gratitude to my friend Mr E. H. Richards, who not only assisted me in much of the practical work of erecting the apparatus but also attended to the experiments during a short period when I was incapacitated owing to a slight accident.

I am also greatly indebted to my friends Mr J. E. Collin and Mr A. H. Hamm for assistance in naming some of the flies observed in the course of the experiments.

The farm manure heap may be purely stable manure or it may be mixed refuse containing the excreta of other animals in addition to horses. Stable manure is usually stored light, i.e. it is not trodden down and compacted, whilst mixed manure may be stored either light or compacted. Such heaps may be out in the open at a considerable distance from dwellings, or they may be quite near to a house or houses. Neither of these conditions resembles the state of affairs which obtains when a stable manure heap occurs in a confined space in a town, and is closely adjacent to many houses and shops, with kitchens, bakeries, etc., in the immediate neighbourhood.

To reproduce the two former conditions suggested above, together with the different nature and treatment of the manure, six experimental heaps were established. Three of these were placed on land adjoining the laboratory, and their relation to their surroundings may be gathered from the accompanying sketch (Fig. 1). The experimental heaps are there marked 1, 2, and 3. They were established on ground forming part of an area which is used by the laboratory for out-door experiments. The nearest dwellings are the cottages shown at a distance of some

220 feet, whilst a hen-run, two garbage heaps, containing principally vegetable refuse, a water closet and an earth closet, are shown at the distances respectively indicated. The main street of the village of Harpenden is some quarter of a mile distant, so that the experiments conducted at the laboratory may be regarded as having been carried on under semi-rural conditions.

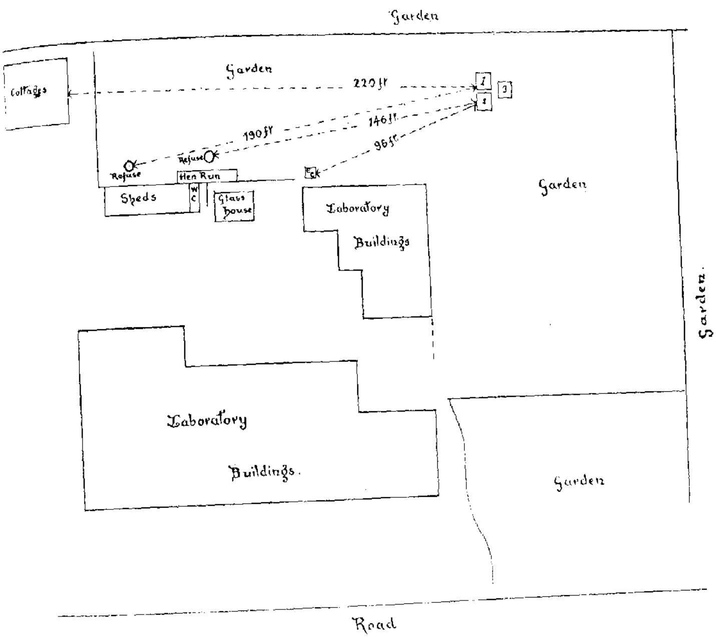

Fig. 1.

It has been found that under certain circumstances the larvae of the flies tend to leave the heaps and pupate in the ground round about so that many flies might escape if the heap alone were enclosed. The traps were therefore designed so as to provide a suitable pupating ground, to limit the lateral wandering of the larvae, and to trap any flies which might emerge from the ground surrounding the heaps.

Reference to Fig. 2 will make the design clear. The drawing represents a section of one of the experimental heaps. A rectangular

trench *G*, about a foot deep and 18 inches wide, was first made and the outer sides lined with a suitable structure consisting of boards attached at the corners to stout posts. The trench was then filled up to the original ground level with a mixture of loose earth and old manure straw forming a light mass suitable for the pupation of the larvae. The extreme hardness of the ground at Harpenden together with the outer lining of wood made it improbable that the larvae would wander beyond this trench. Resting on the outer edge of the original block of ground *F* was a wood frame about 12 inches deep and 5 feet square, *A*.

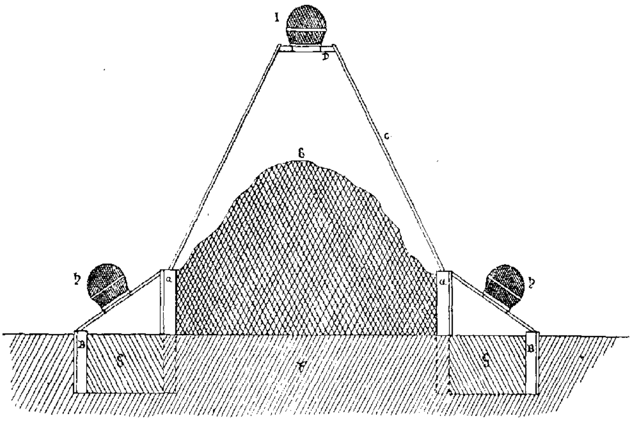

Fig. 2.

This served as a container for the manure *E*. The trench *G* was covered in with unbleached cheese cloth attached to the inner and outer frames, and on strips of wood having central holes, ordinary wire balloon traps were fitted with a sliding arrangement enabling them easily to be removed and replaced. At the four corners of the inner frame stout canes were set up and joined to a small board *D*, which also carried a fly trap. A tent-like cover of cheese cloth was then made to fit over this framework and was fastened down with tape and tacks all round the inner wood frame. In this way it was possible to note the numbers and kinds of flies which hatched from the heap proper and from the trench respectively. No bait was used, it being found that the phototropic tendency of the flies was sufficient to cause them to enter the traps, and it is certain that very few failed to do so. The general

appearance of the completed traps is shown in the photograph herewith, which represents those on the laboratory ground. It may be remarked that unbleached cheese cloth is superior to the bleached quality, in that it is cheaper, stronger, and transmits less light.

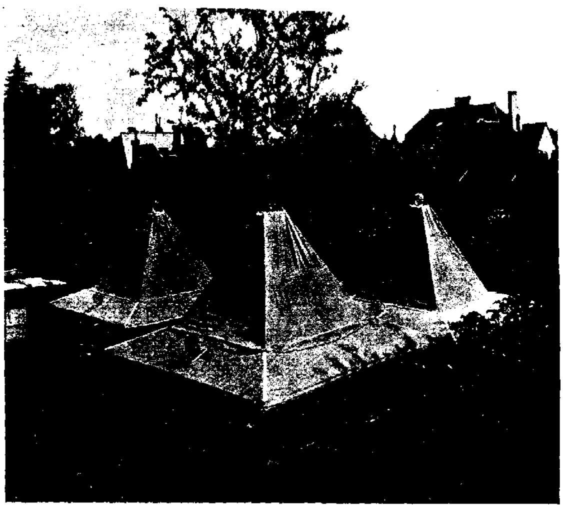

Fig. 3.

Experiment I. On June 22nd a heap was started at the laboratory, one barrow load of horse manure from neighbouring army stables being placed upon it daily. By the 25th the temperature of the centre of this heap had risen to 75° (all temperatures are given on the Centigrade scale) and on the 28th it had fallen to 65°. The temperature fell slowly to 54° on July 6th, when the heap was completely covered in, the quantity of manure being estimated at about 14 cwt. On July 8th the temperature of the heap was 47°, and on the 9th two flies were found in the top trap, one being *M. domestica*. On July 11th one more of the same species hatched out. On July 21st the temperature of the heap was 20°, and on the 26th 23°. On July 29th the heap was opened out and cleared away. The total flies of all kinds which hatched from this heap numbered 16 and were of the following species:

Eristalis tenax L. ...	...	1
Musca domestica L.	...	3
Stomoxys calcitrans L.	...	5
Fannia canicularis L.	...	1
Chortophila cilicrura Rdi. ...		4
Hydrotaea armipes F.	...	2

The result does not support the belief that any of the flies taken were breeding to an appreciable extent in the material used. The manure had ample opportunity of becoming infected either at the army stable or at the laboratory. During this period *M. domestica* was not by any means commonly observed in the neighbourhood.

Experiment II. As a control and in order to discover whether there was anything in the experimental method which might inhibit the growth and development of the larvae, a quantity of horse manure was obtained from a stable closely surrounded by houses and adjacent to a bakery. This material was treated precisely as in Experiment I, except that it was all put on the heap at once and immediately covered in. This was done on July 30th. By August 12th flies had practically ceased to hatch out, and during the thirteen days the following were trapped from the heap:

Musca domestica L. ...	...	798
Stomoxys calcitrans L. ...	...	31
Chortophila cilicrura Rdi.	...	22
Fannia canicularis L. ...	...	4
Hydrotaea armipes F. ...	...	10

This experiment showed in a marked degree the effect of such attractive adjuncts as a bakery and numerous houses in close proximity to the manure bin. The flies did not hatch in great numbers from the trenches, the proportion of *M. domestica* being:

Direct from heap ...	...	682
From trenches ...	...	116

which gives a proportion of over 85 per cent. hatched direct from heap. The highest temperature recorded for this heap was about 50°. This difference in temperature does not however account for the difference in the number of the flies, as careful examination of Heap 1, before it was covered in, showed that it was not really infected, whilst the larvae could easily be seen in Heap 2.

Experiment III. Mixed material, principally horse and cow manure, was obtained from a neighbouring farm and placed on a trap at the laboratory prepared as already described. It was then well trodden down so as to represent the compacted form of storage. This was completed on June 29th. On July 1st the temperature at centre was 42°, on July 5th 55°, and on July 8th 58°. It subsequently fell on July 21st to 40°, but rose again two degrees on July 26th. The heap was covered in on July 12th, and remained closed till August 5th. During that time the following flies were trapped therefrom:

Eristalis tenax L.	8
Stomoxys calcitrans L.	8
Sargus cuprarius L.	15
Chrysomyza demandata F. ...	2
Fannia canicularis L.	6
Chortophila cilicrura Rdi. ...	9

There is a complete absence of *M. domestica*, the material having failed to become infected either at the laboratory or at the farm whence it was obtained. Most of the flies came from the heap direct.

Experiment IV. A heap of material similar to that used in Experiment III was established on June 29th at the laboratory. The manure was however in this case laid light without any treading. On July 1st the temperature was 57°, on the 5th 60°, on the 8th 38°, on the 21st 26°, and on the 26th 35°. The heap was covered in on July 12th, and remained covered till August 5th, during which period the following flies were obtained:

Eristalis tenax L.	13
Stomoxys calcitrans L.	9
Chortophila cilicrura Rdi. ...	14
Scatophaga stercoraria L. ...	4
Sargus cuprarius L.	2
Fannia canicularis L.	3

This heap produced 45 flies as against the 18 in Experiment III. All but three came from the heap direct. The total absence of *M. domestica* is again noticeable.

Experiment V. An experimental heap was established near the farm buildings belonging to the Rothamsted Experimental Station, and over a mile from the laboratory. The position of this and other heaps referred to as "at the farm" scarcely requires illustration. With the exception of two small cottages some 70 yards distant, there are no dwellings near these buildings, which include a stable for horses

having behind it a large manure shed in which manure is stored in large quantities. The heaps used in this and other experiments at the farm were trenched and enclosed precisely as already described, and were placed some 20 yards from the stable door. Upon Heap 4 was thrown a barrow load of fresh horse manure every day, taken direct from the stable adjoining. The heap was started on June 28th and covered in on July 14th, and remained covered till August 4th. From it there hatched out only 26 flies, of which 16 were *Calliphora erythrocephala*, 5 *Chortophila cilicrura*, and 3 *Fannia canicularis*. Two others were small flies of undetermined species. No examples of *M. domestica* were obtained. The preponderance of "Blue bottles" is rather remarkable, and may have been due to a dead vole or some other small animal having got into the heap. Half of them came from the trench traps.

The highest temperature recorded for this heap was about 50° though it was probably higher at some time during my temporary absence owing to a slight accident.

Experiment VI. Close to the heap used for Experiment V some compacted mixed manure was trenched and enclosed as before. This heap was covered in about July 14th after being open to infection for 15 days. It remained covered till August 9th. The highest temperature recorded was 50°. During the period named the following 57 flies were obtained:

Eristalis tenax L.	3
Stomoxys calcitrans L.	2
Sargus cuprarius L.	10
Hydrotaea armipes F.	24
Fannia canicularis L.	17
Cordylurid Sp.?	1

Of the above only two came from the trench, both being *E. tenax*.

Experiment VII. A heap corresponding to that used in Experiment VI was made near the farm buildings. Mixed manure was laid on it light instead of compacted. The heap was enclosed about July 14th after being open to infection for 15 days, and remained closed till August 12th. From this heap the following flies emerged:

Ophyra leucostoma W.	36
Stomoxys calcitrans L.	4
Sargus cuprarius L.	13
Chortophila cilicrura Rdi. ...	37
Chrysomyza demandata F. ...	6
Fannia canicularis L.	3

The heap thus produced about 100 flies, all except one coming from the heap direct. It is remarkable that it produced nearly double the number of flies obtained from that used in Experiment VI, and it might be supposed that the loose laying of the manure had affected the figures. This supposition is not however supported by comparison with Experiments III and IV.

Experiment VIII. A small heap of garden and kitchen refuse behind the laboratory was covered over with a packing case and a trap fixed thereon. The refuse contained potato peelings, pea and bean pods, leaves, scrapings of a small hen coop, etc. The refuse was covered over on July 28th and remained closed till August 11th. During this period the following flies were trapped:

Muscina stabulans Fln....	...	13
Fannia canicularis L. ...	...	17
Chortophila cilicrura Rdi.	...	13
Ophyra leucostoma W. ...	...	4

This experiment was intended to test garden refuse as a breeding place for *M. domestica* under the conditions obtaining at the laboratory, and also in the hope of breeding *Musca autumnalis* De G.[1], which species was fairly abundant in the garden. Neither species emerged from the material.

Experiment IX. There is behind the farm buildings mentioned in Experiment V a large manure shed, the floor of which is cemented forming a kind of tank about 12 inches deep, and having an area of about 660 square feet. Here there was an accumulation of manure and straw taken from the stable adjoining, the sweepings from the stable being thrown on to it daily. It therefore contained both old and fresh manure, and an area of some 25 square feet was covered over with a tent of cheese cloth having a trap on the top. The lower edge of the tent was not fixed close to the cement but was heaped up with straw all round. Doubtless a good many flies escaped round the bottom. On the other hand many were caught and these proved to be nearly all *Stomoxys calcitrans* of which some 453 were taken in the ten days from August 9th to August 19th. Had the whole area of the manure yard produced flies at this rate, the total output would have been nearly 1200 per day, though a lower output is indicated by Experiment XVI. During the period only three *M. domestica* were taken together with a few *Anthomyidae*. Towards the end of this period *M. domestica* became more numerous about the stable.

[1] Formerly known as *Musca corvina*.

Experiment X. Heap 1 was re-opened and the contained horse manure exposed for about a week. After closing in again no flies of any kind emerged.

Experiment XI. Heap 2 containing mixed manure was re-exposed and afterwards trapped. No flies were obtained.

Experiment XII. Heap 6 containing mixed manure was submitted to a second infection period but produced no flies.

Experiment XIII. Heap 3 was refilled with horse manure obtained from a large stud stable in the neighbourhood. This establishment is right away from dwellings, and precautions are regularly taken to disinfect the manure. That supplied for the experiment had not been treated in any way. The heap was made up on August 24th. On the 25th numbers of small maggots were observed on the surface, and these were evidently suffering from the heat. The temperature on the surface exactly where the maggots were wriggling was found to be 42°. Two inches below the surface it was 57°, whilst the centre of the heap gave 65°. A few *M. domestica* were observed inspecting the heap. Towards evening numbers of the maggots were found to have been killed by the heat. On August 30th the heap was completely enclosed. By September 3rd one *M. domestica* and several small *Anthomyidae* had appeared in the top trap.

The traps of this heap were cleared on September 6th, when four *M. domestica* were taken. The experiment continued till September 10th, the total flies taken being:

M. domestica L.	12
Limnophora septemnotata Ztt. ...	37

Experiment XIV. Heap 4 at farm having been cleared out, fresh horse manure from the adjoining stable was placed in it in such quantities as were available from day to day. The heap was finally closed up on August 18th, having been open to infection for some 12 days. By August 24th no flies of any kind had emerged. By September 7th no *M. domestica* had been produced, but 18 *Fannia canicularis* were taken from the top trap and five from the sides. The experiment was continued till September 10th, by which date the following flies had been taken:

Stomoxys calcitrans L.	3
Fannia canicularis L.	14
Phaonia querceti Bouché ...	2
Chortophila cilicrura Rdi. ...	17
Calliphora erythrocephala Mg. ...	1

Experiment XV. On August 24th Heap 5 was again started with fresh horse manure from the adjoining stable. On August 30th the heap was closed in. Some of the manure in this heap had been purposely exposed for five or six hours close to the door of the stable where several *M. domestica* could be seen flying about. On September 3rd the traps of this heap were cleared and found to contain 6 *M. domestica*. Cleared again on September 7th, 5 were taken. Up to September 10th no more flies emerged. Two *Calliphora erythrocephala* were found in the side traps.

Experiment XVI. A wooden trap covering an area of about 9 square feet was placed in various positions on the permanent manure yard at the farm for 2 or 3 days at a time. In several cases no flies of any sort were caught, but in one position, at date about August 30th, it captured 16 *M. domestica*, 2 *S. calcitrans*, and 1 *F. canicularis*. Allowed to remain in the same place for several days longer no further flies were obtained.

Experiment XVII. A quantity of pure horse manure which had been sent to the laboratory for experimental purposes other than in connection with flies was found to have become infected in two or three days and contained many larvae of *M. domestica*. This material, in quantity about a bucketful, was covered over with a box trap. Examined from time to time the larvae apparently thrived but they all disappeared by the beginning of September, and by September 10th no flies had emerged. The slow development was doubtless due to the perfectly cold conditions owing to the small quantity of manure.

Experiment XVIII. At a cottage near the farm buildings it was found that the kitchen and garden refuse were placed in a pit in the ground some 20 or 30 yards from the house. When examined this pit was sodden with water and very offensive. Great numbers of flies were buzzing about it, though *M. domestica* was not in evidence. *L. caesar* was perhaps the commonest fly observed. A box trap was placed over a part of this rubbish pit and flies taken from time to time. In about a week some 78 flies were captured but only 1 example of *M. domestica* was included. The totals were as follows:

Musca domestica L.	1
Hydrotaea dentipes F.	22
Eristalis tenax L.	3
Eristalis arbustorum L.	4
Syritta pipiens L.	11
Ophyra leucostoma W.	13

Chortophila cilicrura Rdi.	...	14
Hydrotaea armipes F. ...	...	6
Spp. ?	...	4

To those who have kept in touch with much of the work recently carried out in connection with the fly problem, perhaps the most striking feature of the foregoing results will appear to be the small number of flies obtained from the experimental heaps. Having some two dozen traps in constant use I fully expected that some assistance would certainly be required in the mere mechanical work of counting and sorting the flies taken.

Thus in Dr Gordon Hewitt's experiments in Canada in 1913[1] a cubic yard of untreated manure used as a control experiment produced 13,332 flies. Large as this number is it appears almost trifling when compared with the figures given by Messrs Cook, Hutchison and Scales[2]. In their Table V, control heaps consisting of 4 bushels of manure (5 cubic feet) are cited as having contained 342,771, 385,403 and 273,520 pupae respectively. Whether such numbers are liable to occur in this country I have no records to enable me to decide, though doubtless numbers comparable to these might occur in say a crowded city area. The most heavily infected manure I was able to obtain, in quantity about 14 cwt. (see Experiment II), produced only some 865 flies, of which 798 were *M. domestica*. The wet summer of 1915 may perhaps account to some extent for the results obtained, though Experiment II was carried out in comparatively fine weather. The flies obtained in this experiment were however quite sufficiently numerous to emphasize the admitted danger of uncontrolled manure heaps in close proximity to dwellings, and we may at once turn to the consideration of the results as applied to heaps under more rural conditions.

Experiments I, III and IV, with horse and mixed manures, produced only three examples of *M. domestica*. During the early part of the season this fly was by no means common, and even later in the summer it was not found to occur in great numbers in or near the laboratory. It was not obtained from garden refuse. A small quantity of horse manure (Experiment XVII) became rather heavily infected at the laboratory though this was undoubtedly due to its having stood for some days actually in the laboratory, and a few flies first attracted into the rooms had soon found the material so conveniently at hand.

[1] *Journal of Economic Entomology*, vol. VII. No. 3, p. 281 *et seq.* 1914.
[2] *U.S. Dept. of Agriculture, Bul.* 245, July 1915.

In Experiment XIII in which the heap was enclosed on August 30th there was every opportunity for *M. domestica* to breed. The heap was continually watched before covering in and it is certain that *M. domestica* did not visit it in great numbers. The small maggots destroyed by the heat were probably those of the *Limnophora*, and in any case the heat would not account for the small number of *M. domestica* since similar conditions obtained in Experiment II. The results obtained with heaps at the farm buildings were more interesting. The first three heaps produced no examples of *M. domestica*, nor was it an easy matter to find this species in or about the stables. Later on the fly appeared in some numbers and random catches with the net gave the following:

Musca domestica L.	44·4 %
Musca autumnalis De G. ...	31·48 %
Muscina stabulans Fln.	24·08 %

To these figures, however, I cannot attach very great importance since from Experiment IX it would seem that *Stomoxys calcitrans* should have been the commonest fly, whereas none were taken in the net. On August 12th I inspected adhesive fly-papers in one of the cottages already referred to as near the farm buildings. One of these papers, stated to have been in use about a fortnight, had caught some 300 flies, almost all *M. domestica*. Another paper in use for the same period contained perhaps a few more. Careful search failed to disclose any special nidus for these flies. The most likely place seemed to be the garbage pit referred to in Experiment XVIII. Although flies of many species were obtained from this pit only one proved to be *M. domestica*. From other experiments it may be assumed that a few of the flies taken on the fly-papers came from the permanent manure yard at the farm buildings. There is nevertheless a strong temptation to suppose that with the well-known tendency of the species to enter houses, the cottages in question formed an attraction for every wandering fly in the neighbourhood and they were thus more likely to be found there than elsewhere. Heap 4 having produced no house-flies from the first filling, a second supply of fresh horse manure was trapped but without producing *M. domestica*. Heap 5 treated in the same way produced altogether 11 of this species. Meanwhile endeavours had been made to find the fly breeding in the large permanent heap already referred to. In Experiment IX 3 *M. domestica* were taken together with about 453 *Stomoxys calcitrans*, whilst from another part of the same heap (Experiment XVI) 16 specimens of the former were secured. The

latter experiment furnishes the only real evidence that *M. domestica* was breeding at all in this heap, and moving the trap on to other areas did not secure any further examples.

I see no reason to regard these experiments as furnishing results other than typical of the conditions under which they were conducted, and in the absence of further evidence it would seem that the following conclusions may be drawn.

That whilst, as already fully recognised, the house-fly is liable to breed in large numbers in stable refuse which is stored in close proximity to dwellings, the governing factor is found in the dwellings rather than in the manure heap, the latter merely serving as a secondary convenience, providing a breeding place for the flies which have been attracted to the houses in search of food.

That the open farm manure heap *far away* from houses is but little frequented by house-flies, and then only later in the season when the insect has become numerous and widely dispersed.

That the spent manure heap, in which fermentation has practically ceased, produces under rural conditions at least practically no flies at all.

That although the farm heap may produce but few house-flies, it is a prolific source of *Stomoxys calcitrans*, and those agriculturists who value the comfort and health of their animals should treat all manure with a view to the destruction of the larvae of this pest.

It should be clearly understood that the above conclusions apply to manure heaps far distant from houses. Where the farm dwelling and the farm buildings adjoin, as they do in so many cases, the danger of the manure heap becomes much greater, particularly where dairies or other food-preparing departments are in proximity to farm refuse.

For the town manure heap, under which category I include that from which the material used in Experiment II was obtained, no regulations can be too drastic, and it is but little creditable to our local authorities, and even less so to the proprietors, that such conditions should be permitted to exist.

Mention has been made of *Stomoxys calcitrans* as a pest to cattle. The "biting house-fly," as it has been called, is a blood-sucking insect possessing great capabilities as a carrier of disease, and it is by no means inclined to distinguish for alimentary purposes between the human and the equine species. There is however another fly, which on account of its numbers and persistency, is probably a far greater nuisance. I refer to *Musca autumnalis* De G. Swarming in the open, it enters houses

somewhat less readily than *M. domestica*, though after *Fannia canicularis* it is perhaps our next most frequent uninvited guest. In autumn it is given to entering houses, especially attics and disused apartments, in enormous numbers, and so-called hibernating house-flies are almost invariably of this species. Professor Poulton has recorded them[1], in his house in the Isle of Wight, in such numbers as to contaminate the secondary water supply. It is not remarkable that the species has received such slight mention in current works on the house-fly since it is only with some practice that it can be distinguished therefrom. The early stages of the species have not so far as I am aware been observed in this country.

I succeeded in breeding the fly from bullock dung. A sample of this material sent to the laboratory for experimental purposes contained numerous bright yellow larvae, some of which I preserved, others being kept till they matured. Having found that *M. autumnalis* De G. resulted from these larvae I inspected bullock dung in the fields and had little difficulty in finding the larvae again. It is probable that this is by no means the only material in which the species may be found though it is evident that it is one of the substances in which it regularly breeds. I hope shortly to collect existing records of this fly and to publish fuller details of my own observations on its life-history.

[1] *Proc. Ent. Soc. Lond.* p. xxi–xxii, 1915.

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STUDIES OF A SCOTTISH DRIFT SOIL.

PART I. THE COMPOSITION OF THE SOIL AND OF THE MINERAL PARTICLES WHICH COMPOSE IT.

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Most of the soil investigations in this country have been conducted at Rothamsted or other parts of South Britain and the soils examined have been chiefly those overlying the stratified rocks of the southern half of England. These, however, are by no means typical of the whole of Britain and research is needed into soils found extensively in Scotland and other parts of Britain which differ greatly in their origin, nature and properties from those which have hitherto been the chief subjects to which British investigators have devoted attention. The various agricultural colleges are taking up the study of the soils of their respective districts, and when the Farm of Craibstone was acquired as an Experiment Station by the North of Scotland College, a series of soil investigations was immediately commenced.

Craibstone is situated about six miles north-west of Aberdeen and is a farm typical of much of the agricultural land of the district and of the North of Scotland generally. The soil is a boulder clay overlying granite and varies much in depth; the subsoil also varies much in depth and texture, passing within a short distance from sand and gravel to clay. The underlying rocks in Aberdeenshire are chiefly granites and metamorphic rocks, and great parts of the neighbouring counties are founded on rocks of a similar nature.

More important, however, than the fundamental formation is the drift material by which it has been overlaid during the ice age and from which most of the soils have been derived. This drift differs

much in different parts of Britain. In places it attains a thickness of over two hundred feet, and quite near may be areas from which it is absent altogether. In some parts it consists of the old soils and subsoils of the original land surface; in others of the ground-down portions of igneous, metamorphic, and very ancient stratified rocks, and between these extremities there are all intermediate stages. Thus the drift of the South-east of England—the Clay-with-Flints, for example—is very different from the drift of the North of Scotland, the one being derived from the old surface soil and late formations, while the other is largely the product of the granitic and metamorphic rocks of the Scottish Highlands. Soils of this latter type cover a great part of North Britain, and Craibstone furnishes a typical specimen of the Northern Drift Soil.

General composition of the material.

The sample used in these investigations was obtained from the South Meethill Field at Craibstone which is being used for field experiments, and in which lysimeters have been built to study the drainage.

The sample used was taken to a depth of nine inches, air dried, and freed from large stones.

The methods of analysis (mechanical and chemical) were, except where otherwise indicated, those adopted by the members of the Agricultural Education Association.

The calcium carbonate present and the "lime requirement" were determined by the methods of Hutchinson and MacLennan[1].

From the mechanical composition it will be seen that the soil under investigation is a coarse sandy soil comparatively rich in organic matter and poor in clay. In determining clay, the liquid was evaporated in bulk and therefore much organic matter dissolved by ammonia was present and was estimated as clay "dried at 100° C.," but even with this included, the total was less than 9 per cent. That this is a great overestimate is shown by the fact that after ignition the weight, *i.e.* the ignited mineral matter of the clay, is less than 4 per cent. of the dry soil.

The chemical analysis shows the soil to be rich in phosphoric acid and potash both "total" and "available."

It contains no carbonate of lime, and has a high "lime requirement," but in spite of this, good crops have been grown for many years without the application of lime.

[1] *Journ. of Agric. Sc.* 1914, **6**, 323-327; 1915, **7**, 75-105.

TABLE I. *Mechanical Analysis.* Dried at 100° C.

	Approx. diam. in millimetres	Dried at 100° C.	After ignition
		per cent.	per cent.
Fine gravel	3–1	10·09	9·93
Coarse sand	1–·2	30·08	29·73
Fine sand	·2 –·04	26·20	25·80
Silt	·04 –·01	14·18	12·47
Fine silt	·01 –·002	9·62	7·63
Clay	·002–0	8·88	3·80
Total of above	—	99·05	89·36
Loss on ignition	—	—	9·69
Dissolved (by difference) ...	—	—	0·95

TABLE II. *Chemical Analysis.* Fine earth dried at 100° C.

	By treatment with strong hydrochloric acid	Soluble in 1 per cent. citric acid (Dyer's method)
	per cent.	per cent.
Sand and insoluble silicates ...	88·81	—
Phosphoric acid	0·36	0·092
Potash	0·49	0·033
Lime	0·53	0·141
Magnesia	0·19	0·031
Loss on ignition (humus, etc.) ...	9·54	
Nitrogen	0·30	
Lime as carbonate	nil	
"Lime requirement" as $CaCO_3$ ...	0·236	

The soils of North Wales have been examined by Robinson[1], and certain of them appear to resemble in many respects those of Scotland. Among other things he found carbonate of lime to be absent from most of the soils examined. This entire absence of carbonate of lime from fertile soils is noteworthy since it has been looked on by many agricultural writers as an essential constituent, and according to Russell[2] "calcium carbonate is often present in small amounts only, but it plays a controlling part in soil fertility."

Chemical composition of the soil fractions.

These preliminary determinations of the general composition of the soil do not throw much light on its history or on the origin of the characteristics which distinguish soils of this type from, for instance, those of the South of England soils which are also of glacial origin.

[1] *Journ. of the Board of Agr.* 1915, **22**, 3.

[2] *Soil Conditions and Plant Growth* (New Edition), 1915, p. 63.

Differences in origin and method of formation give rise to differences both in physical structure and in chemical composition. The differences in physical structure are measured, though only in a crude way, by mechanical analysis, by which the particles of different sizes are separated into arbitrary groups. Chemical composition is usually determined by treatment with a conventional strength of acid. For certain purposes these determinations are sufficient, but for a close comparison of soil types much more is needed. Even complete mineral analysis of the whole soil by fusion or treatment with hydrofluoric acid does not help us much. We have endeavoured to gain further information as to the origin and constitution of this soil by subjecting the different mechanical fractions to ultimate analysis and comparing the results with those obtained elsewhere by others.

Analysis of the fractions of Craibstone soil.

A portion of the prepared sample was fractionated by the ordinary method of mechanical analysis, and the fractions, after ignition, analysed by fusion methods. The results are expressed in Table III as percentages of the relative fractions, and in Table IV as percentages of the total soil.

TABLE III. *Ultimate analysis of mechanical fractions.*

(Calculated as percentages of dry mineral matter of fractions.)

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5
Fine gravel ...	84·96	8·56	1·10	0·88	0·36	1·49	1·58	0·07
Coarse sand ...	83·92	9·34	1·12	1·79	0·38	1·78	1·21	0·08
Fine sand ...	73·87	13·47	4·21	3·05	1·05	1·73	1·53	0·12
Silt	70·15	14·04	5·86	2·15	1·06	1·48	3·89	0·21
Fine silt ...	67·21	18·91	7·85	1·45	1·63	2·51	1·27	0·29
Clay	44·08	27·64	21·81	0·58	1·61	1·10	0·96	0·36

TABLE IV. *Ultimate analysis of mechanical fractions.*

(Calculated as percentages of total dry soil.)

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	Total
Fine gravel	8·44	0·85	0·11	0·09	0·04	0·15	0·16	0·01	9·85
Coarse sand	24·96	2·78	0·33	0·53	0·11	0·53	0·36	0·02	29·62
Fine sand	19·05	3·48	1·09	0·79	0·27	0·45	0·39	0·03	25·55
Silt	8·75	1·75	0·73	0·27	0·13	0·18	0·49	0·03	12·33
Fine silt	5·13	1·44	0·60	0·11	0·12	0·19	0·10	0·02	7·71
Clay	1·68	1·05	0·83	0·02	0·06	0·04	0·04	0·01	3·73
Total	68·01	11·35	3·69	1·81	0·73	1·54	1·54	0·12	88·79

In considering the figures in Tables III and IV it is to be remembered that the method of mechanical analysis adopted involves the treatment of the soil with dilute hydrochloric acid before fractionation is performed, and that therefore all compounds easily soluble in acid were removed and are not shown in the analyses. Table II shows that appreciable quantities of phosphoric acid, potash, lime, and magnesia were dissolved from the original soil by dilute citric acid. No doubt quantities of all these as well as of iron and alumina were dissolved by the dilute hydrochloric acid used before the mechanical separation into fractions was commenced. In the case of phosphoric acid much the greater part of this constituent present in the soil is easily soluble in dilute hydrochloric acid, for whereas Table II shows that the soil contained 0·36 per cent. of phosphoric acid soluble by digestion in strong hydrochloric acid, Table IV shows that only 0·12 per cent. was found in the whole of the mechanical fractions.

Table III shows that, as has been found by all previous investigators of this subject, the percentage of iron and alumina increases and the percentage of silica decreases with a decrease in the size of the particles. In the case of other elements the results of different investigators do not agree so well, but the majority of workers found an increase of potash, soda, lime, magnesia, and phosphoric acid in the smaller particles. The evidence with regard to some of these is, however, very conflicting.

Puchner[1] working on three different soils—a heavy loam, a silty soil (loessial) and a coarse sandy soil from gneiss—found the content of lime, magnesia, and phosphoric acid to be irregular, and that of silicic acid, soda, and potash to be smaller in the finer fractions.

Schneider[2], for a residual soil from the disintegration of augite-andesite, found that the percentage of lime decreased with the size of the particles, while Loughridge[3] found the lime irregular, and Clerk, Gortner and Vail[4] found the highest percentage of this constituent in the silts, and the lowest in the clays.

Schneider[5] found the percentages of magnesia and phosphoric acid irregular.

In Craibstone soil the percentage of phosphoric acid in the fractions increases regularly as the size of the particles becomes less. This is in agreement with the results of most workers. It indicates that there

[1] *Landw. Vers.-Stat.* 1907, **66**, 463

[2] *Amer. Jour. Sci.* 1888, **36**, 236.

[3] *Amer. Jour. Sci.* 1874, **7**, 17.

[4] *Amer. Chem. Jour.* 1908, **39**, 163.

[5] *loc. cit.*

is a greater percentage of phosphoric acid present in highly insoluble forms in the finer particles of the soil; but it is to be remembered that, as has been shown above, the greater part of the phosphoric acid of the soil was removed during the preliminary treatment with dilute hydrochloric acid before the mechanical fractions were separated.

Lime, on the other hand, shows a maximum percentage in the fine sand and falls to a minimum in the clay, while potash and soda are irregular, but both show their smallest percentages in the clay. A similar fall in the case of lime was found by Schneider in the case of the clay from the residual soil from augite-andesite already referred to. This soil was derived from the Rockland Ridge, Washington. On the other hand most investigators have found the highest percentages of potash and lime in the finest fractions.

Table IV shows the distribution in the different mechanical fractions of the constituents calculated as percentages of the total dry soil. The interest of this table lies in the fact that it brings out clearly how large a store of potential food material is present in the coarser fractions which constitute so large a proportion of Craibstone soil. For instance in the case of lime the greatest proportion is present in the fine sand, and over two-thirds of the total lime and nearly two-thirds of the total potash are present in the coarse sand and fine sand taken together. On the other hand the clay contains only a very minute proportion of either the potash or lime of this soil. Robinson (*loc. cit.*) considers the richness in potash of the soils of North Wales due to the potash minerals in the fractions usually classed as sand and gravel.

The connection between the nature and origin of a soil and the composition of its mechanical fractions.

While in general the percentage of silica is found to decrease and the other elements to increase in the finer fractions, the relative decreases and increases differ very much in different soils. These variations are connected with differences in the nature of the soils and in the conditions under which they were formed and at present exist.

There have been at least three processes at work which influence the composition of the fractions, and may lead to differences in soils which were in origin alike.

(*a*) *Mechanical grinding.* In the grinding down of rocks in the process of soil formation, whether by glacial action or by water, the soft materials are most readily powdered and consequently there is a large proportion of these in the finest fractions.

(*b*) *Action of solvents.* Certain substances are much more readily dissolved than others, *e.g.* in granite the felspars are more readily attacked than quartz. This again leads to some minerals occurring more frequently than others in certain fractions.

(*c*) *Absorption and redeposition of dissolved matter* on the surface of the soil particles takes place through changes of temperature and concentration, and other changes affecting the conditions existing in the soil solution.

The composition of all the fractions of a soil will be influenced by the extent to which these three processes have been carried during the soil formation. Though these processes all operate to some extent in practically every case and produce that rough general similarity in chemical composition which is found to exist in particles of similar grade from widely different soils, sometimes one process predominates and sometimes another and hence considerable differences arise in all grades of particles between soils of different history. For example, where solvent action has not proceeded far and the weathering is chiefly mechanical, the fractions will differ in chemical composition from those of soils which have long been subjected to the action of solvents. Even mechanical forces give rise to different types of chemical composition in similar mechanical separates, for the mechanical action of water is more selective than that of ice, and, other things being equal, there would tend to be a greater proportion of hard materials in the silts and clays of glacial origin than in those due to attrition by running water.

The effect of differences in nature and origin on the chemical composition of the separates was drawn attention to by Dumont[1]. He showed that two soils containing about the same proportion of potash (0·894 and 0·853 per cent. respectively) had very different percentages in their mechanical fractions. In one, a fine grained soil from an experimental field at Grignon, the coarse sand contained 0·864 per cent. of potash, the fine sand 0·992 per cent., and the clay 0·940 per cent.; while in the other, a coarse sandy granitic soil from Creuse, the coarse sand contained 1·33 per cent., the fine sand 0·58 per cent., and the clay 0·51 per cent. When expressed as percentages of the whole soil, the difference in the distribution of the potash is even more striking, for the soil from Grignon contained 16·8 per cent. of clay and 17·2 per cent. of coarse sand as compared with 4·5 per cent. of clay and 44 per cent. of coarse sand in that from Creuse.

[1] *Comptes Rendus*, 1904, **138**, 215–217

Failyer, Smith and Wade[1], of the U.S. Bureau of Soils, studied the separates of a large number of soils of the United States, and in their report on "The Mineral Composition of Soil Particles" they give a useful *résumé* of the whole subject. In their mechanical analyses they divided their samples into three grades only, namely, sand (2–·05 mm.), silt (·05–·005 mm.), and clay (·005–0 mm.). Phosphoric acid, potash, lime, and magnesia were determined in these fractions by fusion methods.

One of the groups of soils thus examined came from the Coastal Plains "which are made up of unconsolidated gravels, sands, silts and clays, derived in most part from the erosion of the Piedmont Plateau and other inland areas. These materials were mainly deposited on the then ocean floor and have been brought to their present level by the elevation of the land areas....While the soils of this region present many diversities among themselves, due to special circumstances affecting their deposition or subsequent history, they all differ much from the parent rock and have been subjected to excessive weathering and leaching." Seven soils of this group were examined.

A second group consisted of residual soils from crystalline and metamorphic rocks. "The method of formation, in addition to pulverisation, has been one of removal of certain parts of the rocks, either by solution or mechanically by moving water or air, leaving the present soil as a residue. The material forming the soil may differ but little chemically and mineralogically from the rocks whose breaking down has produced the soil, or it may depart much from them." Only three soils of this group were examined.

A third class examined consisted of soils of glacial origin. This group "includes soils formed from material deposited by glaciers or this material somewhat reworked by water, and also loessial soils, consisting largely of particles the size of silt, which have been carried from other glacial areas and deposited over the underlying material....The glacial soils consist largely of crushed rocks. Much of the material composing them has not been profoundly weathered. They are therefore quite similar in composition to the residual soils, and hence differ from those of the Coastal Plains." Ten soils of this class were examined.

The soils of each class examined by Failyer, Smith and Wade differ considerably from each other, but show certain general similarities among those of the same class. Each class exhibits distinct differences from the other classes. In particular the soils of the Coastal

[1] *U.S. Bureau of Soils Bull.* **54**, 1908. The Mineral Composition of Soil Particles.

TABLE V. *Chemical analysis of fractions of American soils.*

(Calculated as percentages of the dry mineral matter.)

	Approx. diam. in millimetres	CaO			MgO			K_2O			P_2O_5		
		Coastal plain	Glacial	Residual	Coastal plain	Glacial	Residual	Coastal plain	Glacial	Residual	Coastal plain	Glacial	Residual
Sand ...	2–·05	·07	1·24	·50	·09	·54	·48	·37	1·72	1·60	·03	·15	·07
Silt ...	·05 –·005	·19	1·30	82	·14	·88	·86	1·34	2·35	2·37	·10	·23	·22
Clay ...	·005–0	·55	2·69	·94	·61	1·80	1·24	1·76	3·08	2·86	·34	·86	·67

TABLE VI. *Comparison of Craibstone and South of England soils.*

(Chemical analysis of mechanical fractions, calculated as percentages of dry mineral matter.)

	SiO_2		Al_2O_3		Fe_2O_3		CaO		MgO		K_2O		P_2O_5	
	Craib-stone	English	Craib-stone	English	Craib-stone	English	Craib-stone	English	Craib-stone	English	Craib-stone	English	Craib stone	English
Fine gravel	84·96	94·4	8·56	3·0	1·10	2·1	0·88	0·4	0·36	0·8	1·49	0·6	0·07	0·06
Coarse sand	83·92	93·9	9·34	1·6	1·12	1·2	1·79	0·4	0·38	0·5	1·78	0·8	0·08	0·05
Fine sand	73·87	94·0	13·47	2·0	4·21	1·2	3·05	0·4	1·05	0·04	1·73	1·5	0·12	0·02
Silt	70·15	89·4	14·04	5·1	5·86	1·5	2·15	0·8	1·06	0·3	1·48	2·3	0·21	0·03
Fine silt	67·21	84·1	18·91	7·2	7·85	2·6	1·45	1·1	1·63	0·2	2·51	3·2	0·29	0·1 (*a*)
		64·3		19·3		7·6		2·2		0·4		5·3		0·4 (*b*)
Clay	44·08	53·2	27·64	21·2	21·81	13·2	0·58	1·6	1·61	1·0	1·10	4·9	0·36	0·4 (*c*)
		49·0		29·8		13·1		1·5		1·0		3·4		0·7 (*d*)

Plains differ greatly as a class from the Residual and Glacial Soils. These differences are dealt with in detail in the original memoir. In order to illustrate the general effects on the composition of their differences in origin we have calculated the average composition of the separates of the three groups of soils, and the results are shown in Table V.

This Table is not given in the original bulletin of Failyer, Smith and Wade, but has been calculated from the figures given in their detailed tables.

Summarising their work, Failyer, Smith and Wade point out:

1. That "as a general rule, the smaller particles of soils are richer in potassium, calcium, magnesium, and phosphorus than the larger particles."

2. That "the concentration of these elements in the finer components is the more pronounced as the soils have undergone more extreme weathering."

3. That "in glacial soils and others resulting largely from mechanical processes, the coarser particles are relatively high in the percentages of potash, lime and magnesia."

Comparing British soils in the same way we find a somewhat similar contrast in the composition of the fractions according to the origin of the soil. A number of English soils from the gault, bargate, brick earth, and clay with flints formations were fractionated and the fractions were analysed by Hall and Russell[1]. The average of these[2] may be taken to represent the much weathered and decomposed minerals of the soil of the South of England as contrasted with the granitic and metamorphic glacial drift of the north-east of Scotland, which though pulverised by glacial action has not undergone the age-long weathering processes of the southern English soils.

In Table VI we have placed side by side our analyses of the fractions of Craibstone soil and the average of the analyses of similar fractions of English soils in order to illustrate the striking differences between the constitution of these two classes of soils. Hall and Russell divide the "fine silt" in their analyses into two parts, shown as (*a*) and (*b*) in Table VI. (*a*) consists of particles from ·01 to ·005 mm. in diameter, while (*b*) consists of particles from ·005 to ·002 mm. in diameter. They also give two sets of figures for "clay," shown in Table VI as (*c*) and (*d*). Under (*c*) is given the analysis of clay from

[1] *Jour. Agri. Sci.* 1911, **4**, 181–223.
[2] Russell, *Soil Conditions and Plant Growth*, 1915, p. 54.

"fertile soils" while under (*d*) is given the analysis from "less fertile soils."

Table VI shows:

(1) That the percentage of silica is smaller in all the fractions in Craibstone soil than in the corresponding fractions of the English soils. In the case of the three coarser fractions of English soil 94 per cent. or over consists of silica. That is, these fractions almost entirely consist of particles of more or less finely powdered silica. Even in the silt about 90 per cent. is silica, and the coarser part of the fine silt contains almost as great a percentage of silica as the fine gravel of Craibstone soil. The granite of the Aberdeen neighbourhood in the unweathered condition contains about 70 per cent. of silica and 18 per cent. of alumina. We may conclude, therefore, from the analyses that the coarser fractions of Craibstone soil contain much unweathered or partially weathered granitic material in addition to silica. This conclusion was confirmed by the microscopic examination of these coarser fractions and by comparison of them under the microscope with similar fractions separated from powdered granite. The granite used for these comparisons was obtained from a local quarry.

(2) The coarser fractions of Craibstone soil are much richer in alumina than the corresponding fractions of the English soils. It is only in the finest fractions, fine silt and clay, that the English soils are at all comparable in respect of alumina with Craibstone soil. To a certain extent the case of iron presents similar differences.

(3) The coarser fractions of Craibstone soil are much richer in potash and lime than the corresponding fractions of the English soils, but the finer fractions are poorer. A similar richness in potash of the coarse fractions was, as we have seen, noted by Robinson for soils of N. Wales. Whereas in the English soils the finest fractions, fine silt and clay, are the richest in potash and lime; in Craibstone soil the clay is the poorest of all the fractions in both potash and lime.

While Craibstone soil thus differs greatly from soils of the south-east of England, there is a general similarity in type, so far as we have data for comparison, between it and the American soils which have been produced by mechanical pulverisation rather than by profound chemical weathering. Thus Craibstone soil is much nearer in type to the Glacial or Residual soils of Table V than to the Coastal Plain soils. On the other hand the South of England soils conform more nearly in type to those of the Coastal Plain than to the Glacial or Residual soils.

CONCLUSIONS.

The general conclusions to be drawn from the chemical composition of the mechanical separates is that Craibstone soil, which may be taken as representative of a large class of glacial drift soils of the north of Scotland, is composed largely of particles which have not undergone profound chemical weathering, but consists of the original granitic minerals mechanically ground with only comparatively superficial chemical alteration.

The coarser particles which form so large a part of this soil contain great stores of lime in particular, and also of other bases such as potash, soda, and magnesia.

There is a wide difference between such a soil as that of Craibstone and soils of the south-east of England, for instance, which are composed of materials which have been subjected to age-long chemical weathering. When, as at Rothamsted, such soils are of glacial origin, they probably represent glacial detritus derived mainly from materials profoundly weathered long before the glacial period.

It is necessary, therefore, to examine carefully the whole circumstances and to exercise much caution before we apply to soils of Craibstone type conclusions arrived at either as to physical and chemical properties or manurial requirements by the study of the soils of the south-east of England.

We wish to express our indebtedness to Mr James Strachan, M.A., B.Sc., now in the Soudan, formerly of this Department, who made the chemical analyses of the mechanical fractions of Craibstone soil.

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CAUSE AND PREVENTION OF RANCIDITY IN PALM NUT KERNEL CAKE.

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ONE of the most common complaints of users of palm nut kernel cake is that it is liable to become rancid on keeping. Rancidity developing in an oil-seed residue like palm nut kernel cake is likely to be due to splitting of the fats of the cake by a fat-splitting ferment or enzyme—a lipase—formed under certain conditions. The resting seeds do not contain lipase, but they are likely to contain a zymogen from which under suitable conditions lipase is formed. The lipase would then split the fats or oils with the formation of rancid-smelling fatty acids. According to Reynolds Green, lipases act most rapidly at 55° C. Their activity is slowed at 60° C. At 72° C. the lipase is destroyed, and, of course, its action ceases.

The following experiments show that rancidity in palm nut kernel cake is due to the formation of a lipase. A quantity of cake was finely ground, and portions placed in a number of bottles. Some were kept dry, others moistened with water. To the moistened samples a little toluene was added to prevent putrefaction. The bottles were well stoppered to prevent evaporation, heated in a water bath as described below, and afterwards kept at various temperatures in an incubator.

These experiments show that palm nut kernel cake when kept warm and moist for some time becomes rancid, but that it keeps well at the ordinary temperature if dry. The production of rancidity is prevented by heating for a long time to 60° C., or for a short time to 70° C. These facts are in accord with the conclusion that the rancidity is caused by the action of a lipase set free from a zymogen present in the seed. The important practical point is that rancidity is prevented by heating for a short time to 70° C.

Sample No.	Treatment	Result
1	Kept dry at ordinary temperature for 10 weeks.	No trace of rancidity.
2	Heated dry for 1 hour at 75° C., then kept for 10 weeks at room temperature.	No trace of rancidity.
3	Moistened and incubated at 25° C.	Rancid in 3 days.
4	Moistened and kept at room temperature.	Rancid in a few days.
5–8	Moistened, incubated at 22° C. for 24 hours to change zymogen to lipase. Then heated to 30° C ½ to 3 hours. Then replaced in incubator.	Rancid in a few days.
9–12	Same as 5–8, but heated at 40° C.	Rancid in a few days.
13–16	Same as 5–8, but heated at 50° C.	Rancid in a few days.
17–20	Same as 5–8, but heated at 60° C.	Sample heated only ½ hour, became rancid in a few days. Samples heated for 1 hour or longer remained sweet.
21–24	Same as 5–8, but heated at 65° C.	Half hour sample rancid, others remained sweet.
25–28	Same as 5–8, but heated at 70° C.	All samples remained sweet for 10 weeks.
29–32	Same as 5–8, but heated at 75° C.	All samples remained sweet for 10 weeks.
33–36	Same as 5–8, but heated at 80° C.	All samples remained sweet for 10 weeks.
37–40	Same as 5–8, but heated at 90° C.	No rancidity, but sample heated for 3 hours had a smell, possibly due to decomposition by long heating.

A second set of experiments was then carried out as follows. Some ground cake was kept warm and moist until it became rancid. It was then ground up with 5 per cent. common salt solution and incubated at 25° C. for 24 hours. The liquid part was then separated by filtration under pressure. It was a brown opalescent liquid with an acid reaction. It was divided into halves, one of which was boiled for 10 minutes.

Emulsions of castor oil, palm nut kernel oil, and coconut oil were made by means of water and gum arabic. Several tubes of each were treated with boiled and unboiled extract of rancid cake as prepared above. Each tube was exactly neutralised with sodium carbonate solution after addition of neutral litmus. All the tubes were then placed in the incubator at 25° C. After a few days all the tubes containing boiled extract were still neutral, whilst those containing unboiled extract had all become acid in 12 hours. This experiment shows that it is possible to dissolve the lipase out of rancid palm nut kernel cake. The lipase thus dissolved will turn other oils rancid if brought into contact with them under suitable conditions.

Finally boiled and unboiled extract were added to six samples of the cake which had been heated to 70° C. and incubated for some time without turning rancid. After a few days in the incubator all the samples (with one exception) to which unboiled extract had been added became rancid, whilst the samples mixed with boiled extract remained perfectly sweet. This experiment shows that extracted lipase can turn cake rancid.

To determine if rancidity is preventable by heating the dry powdered cake, samples were treated as follows:

Sample No.	Treatment	Result
1–3	Dry powdered cake heated at 30° C. for 1 hour, moistened, toluene added and placed in incubator at 28° C.	In less than a week all three samples became quite rancid.
4–7	Heated at 40° C. for 1 hour, otherwise treatment same as 1–3.	Ditto
8–11	Same, but heated at 50° C.	In a week, three quite rancid, one only slightly so. In 10 days the fourth sample also was quite rancid.
12–15	Same, but heated at 60° C.	Three quite sweet after 17 days, one had a slight trace of rancidity.
16–19	Same, but heated at 75° C.	No rancidity in any case after three weeks.
20–23	Same, but heated at 80° C.	Ditto
24–27	Same, but heated at 90° C.	No rancidity after a fortnight in three samples, but the fourth was slightly rancid.
28–32	Same, but heated at 100° C.	No rancidity in any case after a fortnight.

Conclusion.

Palm nut kernel cake, if kept dry and cool, remains sweet for at least 10 weeks. If kept moist and warm it becomes rancid in a few days. The cake contains a zymogen which under the influence of warmth and moisture forms a lipase. The lipase then turns the oil rancid. The lipase can be destroyed by heating the moistened cake to 70° C. for a short time. If the dry cake is heated the zymogen is usually destroyed, but dry heating is not so certain to destroy it as heating when moist.

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THE FUNGICIDAL PROPERTIES OF CERTAIN SPRAY-FLUIDS.

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Introductory.

The object of the experiments described below was to establish more clearly to what the fungicidal value of alkaline sulphide solutions is to be attributed.

For this purpose a study was made during 1914 and 1915 of the fungicidal action of certain chemicals, principally sulphides, on species of the "powdery mildews" (*Erysiphaceae*) under as exact conditions as possible. Information, based on carefully controlled experiments with actively-growing patches of the mildew, appears to be entirely lacking, notwithstanding the large amount of attention which has been given to the subject.

The economic importance of combating these mildews is very considerable. To take one instance—that of the American Gooseberry-mildew—it has to be recognised that the continuance of the commercial cultivation of this fruit depends upon a satisfactory spray being found. In this connection the lime-sulphur wash has proved, under practical conditions[1], of great value in protecting the gooseberry bush from early attacks of the mildew, but the strongly-adherent deposit produced by this wash renders its use objectionable for later sprayings on account of the disfigurement caused to the berries[2]. A solution of "liver-of-sulphur" leaves no visible deposit and has been commonly recommended against the American Gooseberry-mildew, but certain experiments

[1] Salmon, E. S., in *Journ. South-Eastern Agric. Coll.* XXII. 403 (1913) [1914].

[2] *Idem, loc. cit.* p. 423.

carried out by one of us[1] in 1913 appeared to throw considerable doubt upon the efficacy of this material as a spray. Moreover, the frequently-observed scorching action on the foliage brought about by solutions of "liver-of-sulphur"[1,2] make it desirable to find some material of fungicidal value which is harmless to foliage and does not mark the berries.

The wash recommended almost universally as efficacious against the class of "powdery mildews" (*Erysiphaceae*) is a solution of "liver-of-sulphur"—generally understood to be a mixture of various sulphides of potassium, although latterly the less valuable sodium carbonate has replaced potassium carbonate in the preparation of "liver-of sulphur" for horticultural purposes. An examination of the literature on this subject, however, reveals the fact that definite information is lacking on the two most essential points, (1) the strength at which the solution is fungicidal; (2) the nature of the constituents of "liver-of-sulphur" which are of fungicidal value.

With regard to the strength at which a solution of "liver-of-sulphur" is fungicidal we find a diversity of statement. English writers[3] give the proportion of 1 oz. to 2–3 gallons (English) of water; i.e. a 0·31 % to 0·21 % solution; Sorauer[4] states that authors recommend a solution containing from 0·25 % to 0·4 %. It may be mentioned that it is not an uncommon practice among hop growers in this country when wishing to combat hop-mildew to add from 1 to 1½ lbs. of "liver-of-sulphur" to the 100 gallons of "hop-wash," i.e. to use a 0·1 % to 0·15 % solution of "liver-of-sulphur." American writers[5] recommend for use against mildews a solution containing 1 oz. to 2–4 gallons (American) of water, i.e. from 0·37 % to 0·18 %[6]. Lodeman[7] states that solutions containing from 0·19 % to 0·75 % of "liver-of-sulphur" are used, without stating what concentrations are used against specific diseases. Bourcart[8] mentions that Vesque recommends spraying with

[1] *Idem, loc. cit.* p. 410.

[2] Chittenden, F. J., in *Journ. R. Hort. Soc.* XXXIX. 373 (1914).

[3] Massee, G., *Diseases of Cultivated Plants and Trees*, p. 56 (1910); Strawson, G. F., *Standard Fungicides*, p. 35 (1903).

[4] Sorauer, P., *Handbuch d. Pflanzenkrankheiten*, II. p. 525 (1908).

[5] Duggar, B. M., *Fungous Diseases of Plants*, p. 90 (1909); Stevens, F. L. and Hall, J. G., *Diseases of Economic Plants*, p. 34 (1910).

[6] It is probable that English copyists have repeated the American formulae, oblivious of the fact that the American gallon of water weighs only 8·34 lbs., and is therefore smaller than the English gallon which weighs 10 lbs.

[7] Lodeman, E. G., *The Spraying of Plants*, p. 163 (1903).

[8] Bourcart, E., *Insecticides, Fungicides, and Weedkillers*, p. 115 (1913) (English translation).

a 1 % solution of "liver-of-sulphur" against *Sphaerotheca pannosa*, although it is not stated whether this solution is intended for use on foliage or not. Hollrung[1] states that Mohr employed against *S. pannosa* on the Rose and Peach a 1·3 % solution of "liver-of-sulphur" containing 1·3 % glycerine, without stating whether the mixture was used in summer or winter. Against *S. mors-uvae*, the American Gooseberry-mildew, Goff[2] recommends the use of a 0·18 % to 0·37 % solution, and Close[3], Beach[4], and Duggar[5] a solution containing 0·37 %. Against the Vine-mildew (*Uncinula necator*) Galloway[6] recommends the 0·37 % solution; against the Cucumber-mildew (*Erysiphe Cichoracearum*) Humphrey[7] recommends as successful a 0·18 % solution.

It has to be remembered that the substance "liver-of-sulphur" is not a chemical individual substance but rather a mixture of a great variety of sulphur compounds, chiefly sulphides and polysulphides of potassium (or sodium) and that its composition varies according to the mode of its preparation. Also, that its composition changes on the material being kept unless precautions are taken to avoid contact with the air. It is clear, therefore[8], that the composition of one sample of "liver-of-sulphur" may differ very widely from another sample which appears to the eye to be equally good, a fact which may perhaps explain to some extent the diversity found in the concentrations recommended for use.

The opinion which has been generally held regarding the mode of action of "liver-of-sulphur" appears to be that this substance is valuable by reason of the fact that on exposure to air its solutions readily deposit sulphur in an extremely fine state of division. It is believed in fact that the soluble constituents of the "liver-of-sulphur"—which are chiefly sulphides and polysulphides—do not act *per se*, although their presence is necessary as giving the required deposit of sulphur. Other views have been put forward attributing the fungicidal action to some oxidation product of the higher sulphides, e.g. the thiosulphate—either present in the spray fluid or produced after spraying on the plant.

[1] Hollrung, M., *Handbuch d. chemischen Mittel gegen Pflanzenkrankh.* p. 44 (1898).

[2] Goff, E. S., in *Journ. of Mycology*, V. p. 33 (1889).

[3] Close, C. P., in *New York Agric. Exper. Stat.*, *Bull.* 161, p. 153 (1899).

[4] Beach, S. A., in *New York Agric. Exper. Station Bull.* p. 114 (1897).

[5] Duggar, B. M., *Fungous Diseases of Plants*, p. 223 (1909).

[6] Galloway, B. T., in *Journ. of Mycology*, VI. p. 13 (1891).

[7] Humphrey, J. E., in *Rep. Mass. State Agric. Exper. Stat.* IX. 222 (1892), and X. 225 (1893).

[8] *Vide Journ. of Board Agric.* XXI. p. 236 (1914).

It is believed also that the alkaline nature of the solutions may aid the fungicidal action of the sulphur, although the sulphur which is deposited on the decomposition of the sulphides is believed to be the chief fungicidal agent. In a recent publication on this subject, Foreman[1] goes further than this as the result of a number of experiments with germinating spores of *Botrytis cinerea* and *Sphaerotheca mors-uvae*, and claims that the most potent fungicidal agent is the free alkali. From this point of view it is interesting to find that caustic alkalies and alkaline solutions have sometimes been used as fungicides. For example, solutions of sodium carbonate ranging from 0·05 % to 2·5 % have been found to inhibit the germination of the spores of certain fungi; a 1 % solution of ammonium carbonate perceptibly hinders the germination of *uredospores*[2].

It would obviously be unsafe, however, to assume that the concentration at which a fungicide is able to inhibit the germination of the spore is that at which it is fungicidal to the well-established actively-growing fungus. It has been pointed out by Wallace, Blodgett and Hesler[3] that a solution which gives satisfactory results when used against spores in the laboratory requires a concentration several hundred times stronger to control the same fungus when growing on the plant. Foreman[4] records that a 0·16 % solution of caustic soda prevents the germination of the spores of *Botrytis cinerea* and *Sphaerotheca mors-uvae*; we have found, however, that a 0·3 % solution does not kill well-developed patches of *S. Humuli*. It is clear that experiments based on the behaviour of spores placed in the fungicide have little practical value as indicating the strength at which the same substance will be fungicidal when used against the growing fungus on the plant.

A substance of more recent introduction for use against "powdery mildews" is iron sulphide. P. J. O'Gara speaks[5] of a spray-fluid containing 0·38 % iron sulphide as being "the standard summer-spray for apple and rose mildew" in fruit-growing districts in Oregon, U.S.A. In some field experiments carried out by one of us[6] in 1911 iron sulphide

[1] Foreman, F. W., "The Fungicidal Properties of Liver of Sulphur" (*Journ. Agric. Science*, III. 401 (1910)).

[2] Hollrung, M., *Handb. d. chem. Mitt.* pp. 49, 50.

[3] Wallace, E., Blodgett, F. M., and Hesler, L. R., "Studies of the Fungicidal Value of Lime-Sulfur Preparations" (*Cornell Univ. Agric. Exper. Station, Bull.* 290 (1911)).

[4] Foreman, F. W., *loc. cit.*

[5] *Leaflet*, Rogue River Valley, Medford, Oregon (1911).

[6] Salmon, E. S., "Report on Economic Mycology" (*Journ. S.-E. Agric. College*, XXI. p. 346 (1912)).

proved a powerful fungicide against the Apple "scab" fungus (*Fusicladium*). An "iron sulphide spray[1]" has been used by W. H. Volck[2] with success in field experiments against the Apple powdery mildew. M. B. Waite reports[3] the successful use of an "iron sulphide mixture" (to which arsenate of lead was added) against fungous diseases of the Apple. The striking results obtained in our experiments with a mixture of iron sulphide and soft soap are recorded below at p. 501.

METHODS.

The plants used in testing the fungicidal value of the various solutions were 1- or 2-year old seedlings of the Hop (*Humulus Lupulus* Linn.) bearing the "powdery mildew" *Sphaerotheca Humuli* (DC.) Burr. The plants stood in an unheated greenhouse, kept as well ventilated as possible. In a few experiments in 1915 Gooseberry bushes in the open, bearing the American Gooseberry-mildew (*S. mors-uvae* (Schwein.) Berk.), were used.

The hop-plants used in the experiments were kept close together, and under the conditions of culture became severely infected with the hop-mildew. The spraying was done during the months of May, June and July. The plant used for spraying was carefully selected as bearing on a number of its leaves young and vigorously-growing patches of the mildew in its conidial stage. In order to make the experiments as strictly comparable as possible only those patches of mildew were used where the growth was so vigorous that the abundant conidiophores had produced masses of ripe, free conidia[4]. On each plant from 2 to 4 leaves, each bearing a large number (10-20) of "powdery" patches, were sprayed (using a hand "atomiser") with the solution, while the same number of leaves bearing exactly similar patches were reserved as "controls." The solution was applied in the finest spray with sufficient force and quantity to wet *thoroughly* all the patches of mildew. The "control" leaf was always on the same plant, and was usually the opposite leaf at the same node. In every experiment made, the mildew on the control leaves continued to grow and extend its patches; it is therefore unnecessary to mention the

[1] The spray used is described by the author as being "a mixture of iron sulphide, gypsum and precipitated sulphur." Arsenate of lead was added to it. The percentage of iron sulphide in the various spray-fluids used was, apparently, from 0·2 % to 0·6 %.

[2] Volck, W. H., in *Better Fruit*, p. 39 (1911).

[3] Waite, M B., *U.S. Dept. Agric. Bureau of Plant Industry Circular*, 58 (1910).

[4] This stage is denoted by the term "powdery" in the details of the experiments given below at p. 480 and sqq.

"controls" in the details of the experiments recorded below. The sprayed leaves were regularly observed at intervals of a few days from the first day after spraying until the action of the solution was determined. Owing to the superficiality of the mildew, and the ease with which the plants could be handled, no difficulty was experienced in accurately determining the biological condition of the fungus.

In preliminary trials it was found that when patches of mildew in an actively growing "powdery" condition are sprayed with aqueous solutions, the spray (even when very finely divided and applied with force) collects in minute drops on the surface of the densely packed conidiophores and conidia, being prevented by the presence of air at these places from uniformly wetting the fungus[1]. When, however, a 0·5 % or 1 % solution of soft soap is added, the wetting power of the solution used is increased to such an extent that it spreads evenly and uniformly through all "powdery" patches[2]. In the case of lime-sulphur, to which soap cannot be added for chemical reasons, 0·125 % or 0·25 % of saponin[3] was added, so as to secure, as far as possible, uniformity in the spreading properties of the sprays used.

Materials Used.

For the sake of clearness, when considering the effect produced by the various spraying fluids used, a brief description of the materials comprising them is desirable. It should be mentioned in the first place that for the purpose of decreasing the surface tension of the spray-fluids and thus increasing their power of *wetting* powdery surfaces, definite quantities of soap have been used in the preparation of most of the solutions employed. In other cases, where for chemical reasons soap could not be used, as in the case of lime-sulphur, its place in the mixture has been taken by saponin[4].

Soap. In all cases where soap has been used alone or in conjunction with other substances the soap used was that known commercially

[1] Mr S. U. Pickering has already called attention to this fact (*11th Report Woburn Exper. Fruit Farm*, p. 119 (1910)).

[2] In some spraying experiments with certain washes carried out under practical conditions in the open, Messrs Barker and Lees (*Report Agric. and Hort. Research Station, Long Ashton*, for 1914, p. 73) found that 2 % soft soap solution did not thoroughly wet the mildew, while a 2 % paraffin emulsion did so.

[3] Mr Pickering (*loc. cit.* p. 159) has pointed out that the action of saponin resembles that of soap in increasing the wetting properties of spray-fluids.

[4] *Vide 11th Report Woburn Exper. Fruit Farm*, p. 159 (1910).

as "Cook's Soap." The sample was rather a fluid type of soft soap which exhibited a neutral or slightly acid character. The total alkali was found to be equal to 11·6 % KOH (or 8·36 % NaOH).

Saponin. The material used was the ordinary white powder sold commercially.

Liver-of-sulphur. Of several samples examined, one supplied by Messrs Baird and Tatlock was selected as being a good sample and suitable for the purpose of this work. It was found to contain 44 % sulphur of which 42·2 % was present as sulphide-sulphur[1]; less than 1 % as sulphate and less than 1 % as sulphite and thiosulphate. The alkalinity was found to be equal to 4–5 % K_2CO_3 and the total alkali, calculated as KOH, equal to 59·6 %—of which 48·8 % was due to potassium. The sample may be considered to be a superior one to anything likely to be purchased by the grower.

Yellow ammonium sulphide. This material was prepared by saturating 200 c.c. of a 10 % solution of ammonia in water at 17° C. with sulphuretted hydrogen, then adding 400 c.c. of 10 % ammonia solution and 1000 c.c. of water. To this mixture 24 grms. of flowers of sulphur were added and when completely dissolved the clear solution constituted the stock solution used throughout this work[2]. The total sulphur present in this solution was found to be 3·7 % of which 2·2 % was present as sulphide-sulphur. Sulphates were absent and only traces of sulphites and thiosulphates could be detected. The sp. gr. of the stock solution was 1·001 at 15° C.

Colourless ammonium hydrosulphide. This was prepared by saturating a 4 % solution of ammonia in water with sulphuretted hydrogen. The amount of "sulphide-sulphur" which was present was found to be 6·72 %.

Colourless ammonium sulphide. The above solution of ammonium hydrosulphide was mixed with an equal volume of 4 % ammonia solution. The quantity of sulphide-sulphur was found to be 3·36 %.

Lime-sulphur. Berger's brand of "lime-sulphur" was used and diluted to the sp. gr. 1·01 and 1·005. At the former concentration the amount of sulphide-sulphur present was found to be 1·43 %.

[1] The estimation of sulphide-sulphur was effected by the volumetric method in which a standard ammoniacal solution of zinc is employed and a solution of nickel sulphate used as an outside indicator.

[2] The method followed in preparing the spray-fluids from the stock solution may be illustrated in the case of that used in Exp^ts. 9 and 10, p. 494, which was prepared by diluting 25 c.c. of stock solution to 200 c.c. with distilled water and then adding 200 c.c. of a 2 % solution of soft soap in distilled water.

Sodium thiosulphate. The ordinary commercial crystalline material was used.

Ammonia. The ammonia solutions used were prepared from a strong solution which contained 24·7 % ammonia (sp. gr. 0·911 at 15° C.) by diluting it with water.

Caustic soda. The substance used was that usually sold in stick form.

Hydrogen sulphide. Distilled water, after having been boiled to expel air, was cooled and saturated with the purified gas. The amount of sulphide-sulphur present was found to be 0·113 %.

Iron sulphide. Two methods were followed in the preparation of this material: (i) a weighed quantity of crystallised ferrous sulphate was dissolved in water and a dilute solution of yellow ammonium sulphide added drop by drop until the formation of iron sulphide seemed complete; (ii) a dilute solution of ferrous sulphate was added to a known quantity of ammonium hydrosulphide solution until no further precipitation occurred. It should be mentioned that when made according to method (i) the iron sulphide remains longer in a fine state of division and is consequently in a better form for applying as a fine spray.

I. Various Substances.

Soft soap.

Hops. 1914.

Exper. 1. *Solution containing* 1 % *soft soap.*

2nd day. The majority of the patches showing a vigorous growth of conidiophores.

3rd day. All the patches of mildew now as vigorous and as "powdery" as before spraying. There was no injury to the leaf-cells at any place.

1915.

Exper. 1. *Solution containing* 1 % *soft soap.*

2nd day. The patches of mildew scarcely checked; all showing an abundant growth of young conidiophores.

3rd day. All the patches now "powdery."

Saponin.

Hops. 1914.

Exper. 1. *Solution containing* 0·25 % *saponin.*

1st day. Mildew little affected.

3rd day. All the patches of mildew vigorous and "powdery."

Sodium carbonate.

Hops. 1915.

Exper. 1. *Solution containing* 0·3 % *carbonate of soda (crystallised) and* 1 % *soft soap.*

2nd day. The mildew scarcely checked; all the patches with numerous immature conidiophores.

3rd day. All the patches now densely powdery.

Sodium thiosulphate.

Hops. 1915.

Exper. 1. *Solution containing* 1 % *sodium thiosulphate and* 1 % *soft soap.*

2nd day. The mildew but little checked; some patches almost "powdery."

8th day. All the patches as "powdery" as on the controls. No injury to the leaf.

Summary of Observations. I.

None of the following substances—soft soap[1], 1 % solution; saponin, 0·25 %; sodium carbonate[2], 0·3 % and soft soap, 1 %; sodium thiosulphate[3], 1 % and soft soap, 1 %—had any fungicidal value.

II. CAUSTIC SODA.

Hops. 1915.

Exper. 1. *Solution containing* 0·3 % *caustic soda and* 1 % *soft soap.*

2nd day. All the patches much checked, with conidiophores all collapsed. Most of the patches with dark rims round them; otherwise no injury to the leaves.

3rd day. All the patches greatly checked, mostly dormant and sterile; a few with, here and there, isolated conidiophores bearing chains of spores.

6th day. Some of the patches with fairly numerous small groups of conidiophores near the centre; most with only a very few scattered conidiophores; some of the patches dead.

[1] See above, p. 478.

[2] G. Dorogin has stated (*Zeitschr. f. Pflanzenkrankh.* XXIII. p. 335 (1913)) that a solution of 0·25 % or 0·5 % of carbonate of soda or carbonate of potash is efficacious against the American Gooseberry-mildew. Hector, J. M. and Auld, S. J. M. (*Gardeners' Chronicle*, Aug. 7, 1915, pp. 79–80) believe that they obtained some evidence in field experiments that a 0·3 % solution of carbonate of soda was detrimental to the American Gooseberry-mildew.

[3] Hollrung, *loc. cit.* p. 50, mentions that Hitchcock and Carleton (*Kansas Exper. Station, Bull.* 38) state that the germinating capacity of uredospores is weakened by prolonged treatment with a 1 % solution of sodium thiosulphate.

8th day. The mildew alive on the majority of the patches and forming small groups of conidiophores or scattered single conidiophores. The leaf-cells at the periphery of each patch brown and dead; microscopical examination showed that the epidermal cells alone at these places were killed.

Exper. 2. *Solution containing* 0·5 % *caustic soda and* 1 % *soft soap.*

1st day. The patches all much checked, with the epidermal leaf-cells at the periphery of each patch darkened. The tip of one leaf, where the fluid had collected, shrivelled.

3rd day. The mildew greatly checked; some patches bearing a few isolated conidiophores towards the centre.

7th day. Most of the patches now showing a vigorous growth of conidiophores—some patches almost powdery.

13th day. Most of the patches quite powdery.

Exper. 3. *Solution containing* 0·5 % *caustic soda and* 1 % *soft soap.*

3rd day. Mildew checked; some patches showing a few conidiophores. The older leaves slightly "scorched" at the tip; the youngest leaves severely "scorched" at the edge and tip; growing tip of shoot not injured.

6th day. Mildew greatly checked; most of the patches dead; the others showing short, weak conidiophores. No further injury produced.

9th day. The patches of mildew now showing vigorous, erect conidiophores; some of the patches "powdery."

Exper. 4. *Solution containing* 0·75 % *caustic soda and* 1 % *soft soap.*

3rd day. Mildew dead or very greatly checked. All the leaves severely "scorched," the injury being in the form of dead patches of cells chiefly at the tip and edges of the leaf, but occasionally elsewhere; the growing tip of shoot not injured. (The "scorching" of the youngest leaves was sufficiently serious to prevent them subsequently from developing normally.)

6th day. All the patches nearly but not quite dead—only a few weak conidiophores present.

9th day. All the patches dead.

Exper. 5. *Solution containing* 1 % *caustic soda and* 1 % *soft soap.*

1st day. The mildew greatly checked; the epidermal cells at the periphery of each patch darkened. The tip of one leaf slightly shrivelled.

3rd day. Most of the patches dormant, and some dying or dead; a few with bases of young conidiophores. No further injury, which was very slight.

7th day. No further growth of the mildew.

9th day. A few of the patches with small clusters of conidiophores.

13th day. A few patches showing small but vigorous tufts of conidiophores; the majority dead or nearly so.

Exper. 6. *Solution containing* 1 % *caustic soda and* 1 % *soft soap.*

1st day. Mildew greatly checked; the leaf-cells underlying the patches turned brownish-black, the injury extending in most cases to the under-surface.

4th day. All the patches dead or dying.

6th day. A few patches showing a few scattered conidiophores at the centre.

10th day. The mildew now practically everywhere dead; no further injury to the leaves.

Exper. 7. *Solution containing* 1 % *caustic soda and* 1 % *soft soap.*

1st day. All the patches of mildew killed, accompanied by the death of the underlying leaf-cells. The tip of each leaf blackened and shrivelled.

4th day. Distinct injury apparent to the tip of each leaf and the margins near the tip.

Exper. 8. *Solution containing* 1·5 % *caustic soda and* 1 % *soft soap.*

1st day. All the patches of mildew greatly checked or killed; accompanied by a blackish-brown discoloration of the underlying leaf-cells, the injury extending to the lower surface.

4th day. On the upper leaves all the patches dead: on the lower leaves most of the patches dead, but some bearing a very few scattered conidiophores at the centre. No further injury to the leaves.

6th day. Only one patch on a lower leaf alive and showing a very few scattered conidiophores.

10th day. The one patch of mildew nearly dead.

Exper. 9. *Solution containing* 1·5 % *caustic soda and* 1 % *soft soap.*

1st day. The mildew greatly checked, or killed; slight injury to the tip and edge of each leaf.

2nd day. All the patches apparently killed; decided injury to the oldest leaves in the form of pale "burnt" areas and curling of margins; to the next oldest leaves in the form of curling of the tip and margins; to the youngest leaves in slight injury to the tip.

6th day. The mildew entirely killed; no further injury to the leaves (this was, however, serious).

Exper. 10. *Solution containing* 1·5 % *caustic soda and* 1 % *soft soap.*

3rd day. The mildew greatly checked. All the leaves badly "scorched,"—the two oldest leaves severely "scorched" at their margins; the two intermediate leaves less badly "scorched"; the youngest leaves so badly "scorched" at their margins that they never developed normally.

9th day. All the patches of mildew dead.

Exper. 11. *Solution containing* 2 % *caustic soda and* 1 % *soft soap.*

1st day. The mildew very greatly checked. All the leaves severely "scorched," the tips and margins curled.

2nd day. All the patches of mildew killed, accompanied by the death of the underlying leaf-cells. All the leaves seriously injured, curled and shrunken at the margins and showing pale "burnt" areas over their surface.

Gooseberries. 1915.

For the purpose of ascertaining the effect of a caustic soda spray upon Gooseberry foliage, a solution of 1·5 % was used on the leaves of two varieties of Gooseberry, viz. Yellow Rough and Lancashire Lad. On Yellow Rough it produced by the first day "scorching" in the form of minute black patches on the youngest leaves only; the extreme tip of one shoot was killed. On the fourth day some of the older leaves showed patches of a brown discoloration and also brown edges; by the tenth day a severe defoliation had occurred. On Lancashire Lad by the first day the youngest leaves only showed "scorching" in the form of minute black patches; on the fourth day some of the older leaves showed brown edges, and by the tenth day a few of the leaves had fallen.

Summary of Observations. II.

Caustic soda was not tried at a lower concentration than 0·3 %. At this strength it has an immediate injurious action on the mildew and at the same time kills the epidermal cells at the periphery of the mycelium of the mildewed patch. The action is not powerful enough, however, at this concentration, nor at the increased concentration of 0·5 %, to kill the mildew, and we find that the mildew recovers gradually until by the ninth to thirteenth day after treatment many of the patches are again powdery with conidia from fresh conidiophores.

Serious injury to the leaf (apart from the portion occupied by the mildew) has been observed at a concentration of 0·75 % which almost prohibits the use of such a solution. At 1 % the mildew is usually killed and the tip of the leaf is usually "scorched" and killed. In Exper. 7 (recorded above), in which the three mildewed leaves were sprayed on both sides with a 1 % solution, all the patches of mildew were killed very satisfactorily and this was accompanied by the death of the leaf-cells underlying and surrounding each patch. Distinct "scorching" injury was produced to the tip of the leaf and adjacent margin.

At the concentration of 1·5 % the risk of serious leaf-injury is so great as to prohibit the use of such a solution. In Exper. 10, the older leaves were very seriously scorched by a 1·5 % solution and while the younger leaves showed only injury at the tip, it was found that this so damaged them that they could not develop properly. In one experiment (not recorded above) twelve hop plants, bearing numerous patches

of mildew on many of the leaves, were thoroughly sprayed with a 1·5 % solution. In this experiment the whole plants were treated, including the youngest leaves and the growing tip of the stem, and each leaf was sprayed on both surfaces. The injury produced by the third day was very marked: many of the leaves were completely discoloured and were more or less rigid, and dying or dead—at a touch they fell to the ground—whereas others were only injured severely at the tip and edges. The growing tips of two plants were killed.

Taking into consideration also the effect produced by this material on gooseberry foliage it seems clear that caustic soda by itself (or with soap) is unlikely to prove a satisfactory fungicide, although the fact that a 0·3 % solution exerts a partial fungicidal action must be taken into account when considering the value of other substances exhibiting alkaline properties.

III. AMMONIA.

Hops. 1915.

Exper. 1. *Solution containing* 0·5 % *ammonia and* 1 % *soft soap.*

1st day. All the patches white and apparently only slightly checked; the bases of the conidiophores everywhere visible.

4th day. The patches powdery or nearly so.

6th day. All the patches powdery.

Exper. 2. *Solution containing* 1 % *ammonia and* 1 % *soft soap.*

1st day. The patches white, slightly checked; bases of conidiophores everywhere visible.

4th day. All the patches powdery or nearly so.

6th day. All the patches as powdery as those on the "control" leaves.

Exper. 3. *Solution containing* 1·5 % *ammonia and* 1 % *soft soap.*

2nd day. The mildew little checked—some of the patches almost powdery. Slight injury to the leaf in the form of minute, brown, "burnt" patches of cells—one or two on each of the three sprayed leaves.

8th day. All the patches now densely powdery; no further injury to the leaf.

Exper. 4. *Solution containing* 2 % *ammonia and* 1 % *soft soap.*

2nd day. The mildew little checked, some of the patches almost powdery. Slight injury to the leaf in the form of minute, brown, "burnt" patches of cells—two or three on each of the three sprayed leaves; the tip of one leaf injured also.

8th day. All the patches now densely powdery; no further injury to the leaf.

Exper. 5. *Solution containing* 4 % *ammonia and* 1 % *soft soap.*

1st day. The mildew much checked on lowest leaf; on the uppermost leaf several of the patches bore short conidiophores. Injury to the lower leaves in the form of slight discoloration (darkening) and curling of the margin.

3rd day. The mildew much checked; most of the patches on the lowest and middle leaves apparently dead; on the uppermost leaf several of the patches with small groups of conidiophores. Injury more apparent; the lowest leaf killed and curled at the margins; the middle leaf with injury in the form of small, brown, "burnt" patches of cells; the uppermost leaf not injured.

7th day. All the leaves now with several patches of mildew bearing vigorous tufts of conidiophores.

Exper. 6. *Solution containing* 8 % *ammonia and* 1 % *soft soap.*

Within two hours of spraying the sprayed leaves had curled, withered, and were dead or dying.

1st day. All the leaves dead and shrivelled.

Summary of Observations. III.

Ammonia at 4 % severely checks the mildew, but does not kill all the patches; at this strength serious injury is produced to the leaf-tissue. At 2 % slight injury to the leaf begins to be caused, in the form of small "burnt" areas scattered over the leaf without reference to the disposition of the patches of mildew; at this concentration ammonia is practically without fungicidal value, some of the patches of mildew becoming almost "powdery" the second day after treatment.

IV. "Liver-of-sulphur[1]."

Hops. 1914.

Exper. 1. *Solution containing* 0·3 % *liver-of-sulphur* (0·13 % *sulphide sulphur* (S.S.)) *and* 1 % *soft soap.*

1st day. Mildew checked.

3rd day. Mildew still checked, but a few fresh conidiophores beginning to be developed on some of the patches.

5th day. Many of the patches now with groups of conidiophores.

8th day. Most of the patches now more or less "powdery."

Exper. 2. *Solution containing* 0·3 % *liver-of-sulphur* (0·13 % S.S.) *and* 0·25 % *saponin.*

1st day. Mildew checked.

3rd day. All the patches beginning to produce conidiophores.

6th day. All the patches now "powdery."

[1] *Vide* Materials used, p. 478.

Exper. 3. Four leaves (each covered with numerous "powdery" patches of mildew) at two nodes were sprayed with the two following solutions, (*a*) and (*b*)—one leaf at each node being used for each solution.

(*a*) *Solution containing* 0·3 % *liver-of-sulphur* (0·13 % S.S.) *and* 1 % *soft soap.*

(*b*) *Solution of yellow ammonium sulphide containing* 0·16 % S.S. *and* 1 % *soft soap.*

1st day. (*a*) and (*b*) Mildew checked.

2nd day. (*a*) All the patches showing renewed growth and developing very numerous conidiophores.

(*b*) All the patches dormant and sterile.

5th day. (*a*) Most of the patches now "powdery"; the remaining patches "subpowdery."

(*b*) As on the 2nd day.

7th day. (*a*) and (*b*) As on the 5th day

11th day. (*a*) All the patches of mildew as vigorous and as "powdery" as though they had never been sprayed.

(*b*) All the patches now dead or dying.

Exper. 4. Opposite leaves bearing numerous "powdery" patches of mildew were sprayed with

(*a*) *Solution containing* 0·3 % *liver-of-sulphur* (0·13 % S.S.) *and* 1 % *soft soap.*

(*b*) *Solution of yellow ammonium sulphide containing* 0·08 % S.S. *and* 1 % *soft soap.*

It was noticeable that the spray did not permeate so well in (*a*) as in (*b*). When the spray was dry, the mildew patches on the leaf sprayed with (*a*) were white in colour, and showed numerous erect conidiophores; with (*b*) the patches were a dingier white, and nearly all the conidiophores had collapsed.

1st day. (*a*) Mildew apparently vigorous and growing.

(*b*) Mildew apparently dormant.

3rd day. (*a*) and (*b*) As above.

5th day. (*a*) Mildew now showing erect clustered conidiophores.

(*b*) Mildew still dormant and sterile.

9th day. (*a*) The patches of mildew now "powdery."

(*b*) The patches of mildew dormant and sterile.

12th day. (*a*) and (*b*) As above.

Exper. 5. *Solution containing* 0·4 % *liver-of-sulphur* (0·17 % S.S.).

1st day. Mildew slightly checked.

4th day. Many patches now with vigorous erect conidiophores.

6th day. Most of the patches "powdery" or "subpowdery."

Exper. 6. *Solution containing* 0·4 % *liver-of-sulphur* (0·17 % S.S.) *and* 1 % *soft soap.*

1st day. Mildew checked.

3rd day. Mildew still much checked.

5th day. Many patches still much checked, and sterile; a few patches now showing scattered conidiophores, or scattered groups of same.

8th day. Most of the patches with groups of vigorous clustered conidiophores.

Exper. 7. *Solution containing* 0·4 % *liver-of-sulphur* (0·17 % S.S.) *and* 1 % *soft soap.*

1st day. Mildew checked.

4th day. All the patches still checked and sterile.

6th day. As above.

10th day. Most of the patches still quite sterile; two or three patches only producing a few tiny clusters of new conidiophores.

Exper. 8. *Solution containing* 0·4 % *liver-of-sulphur* (0·17 % S.S.) *and* 0·25 % *saponin.*

1st day. Mildew checked.

3rd day. On one leaf (*a*) all the patches dormant and sterile; on the other leaf (*b*) some patches producing a few conidiophores.

5th day. (*a*) as above; (*b*) the patches growing vigorously and almost "powdery."

8th day. (*a*) as above; (*b*) most of the patches now "powdery."

Exper. 9. *Solution containing* 0·6 % *liver-of-sulphur* (0·26 % S.S.).

1st day. Mildew slightly checked.

4th day. Some of the patches killed and brown, with death of the subjacent cells extending through to the under-surface of the leaf; other patches living and showing a few erect conidiophores.

6th day. As above.

10th day. The majority of the patches dead; a few patches bearing a few scattered conidiophores.

Exper. 10. *Solution containing* 0·6 % *liver-of-sulphur* (0·26 % S.S.) *and* 1 % *soft soap.*

1st day. Mildew checked.

5th day. All the patches checked and sterile.

8th day. Many of the patches quite sterile; a very few patches with a few conidiophores, but none vigorous.

Exper. 11. *Solution containing* 0·6 % *liver-of-sulphur* (0·26 % S.S.) *and* 1 % *soft soap.*

1st day. Patches all checked, dormant and sterile.

4th day. One leaf with all the patches dingy white, sterile and apparently dying; the other leaf with most of the patches sterile, but with one or two patches showing fresh growth.

10th day. On one leaf all the patches dead; on the other leaf all the patches dead except two, where tiny clusters of new conidiophores were visible.

Exper. 12. *Solution containing* 0·6 % *liver-of-sulphur* (0·26 % S.S.) *and* 1 % *soft soap.*

1st day. Mildew checked, but many conidiophores still visible.

3rd day. The conidiophores still visible on many patches, but no further development of others.

8th day. All the patches greatly checked, many quite sterile and dead or dying; on each leaf, however, two or three patches showed minute groups of conidiophores, usually towards the centre of the patch.

12th day. Each leaf now with some patches bearing vigorous conidiophores—here and there even "powdery."

Exper. 13. *Solution containing* 0·6 % *liver-of-sulphur* (0·26 % S.S.) *and* 0·5 % *soft soap.*

1st day. Mildew checked, but erect conidiophores visible.

3rd day. All the patches still greatly checked.

5th day. Many patches on both leaves developing conidiophores; a few patches almost "powdery."

8th day. As above.

12th day. Many patches now almost or quite "powdery."

Exper. 14. *Solution containing* 0·6 % *liver-of-sulphur* (0·26 % S.S.) *and* 0·25 % *saponin.*

1st day. Mildew checked.

3rd day. As above.

5th day. Most of the patches still checked; a few patches producing a few conidiophores.

8th day. All the patches now producing abundant conidiophores.

Exper. 15. *Solution containing* 0·8 % *liver-of-sulphur* (0·34 % S.S.).

1st day. Patches of mildew more or less checked.

4th day. Most of the patches showing some erect conidiophores.

6th day. Mildew very severely checked; some of the patches brown and dead, accompanied by the death of the whole area of the subjacent leaf-cells (extending through to the under-surface of the leaf); some patches showing a few conidiophores.

10th day. Nearly all the patches killed; a few still bearing a few scattered conidiophores.

Exper. 16. *Solution containing* 0·8 % *liver-of-sulphur* (0·34 % S.S.) *and* 1 % *soft soap.*

1st day. All the patches of mildew checked, dormant and sterile.

4th day. All the patches of mildew quite sterile (the tips of both of the leaves yellow and shrivelled, due to the accumulation there of the fluid).

6th day. All the patches sterile; no further injury to the leaves.

10th day. All the patches dead.

Gooseberries. 1915.

In one experiment two shoots of a Gooseberry bush in the open infested with the American Gooseberry-mildew (*Sphaerotheca mors-uvae*) in its "powdery" conidial stage were sprayed in July, with respectively a solution of "liver-of-sulphur" containing 0·13 % sulphide-sulphur and a solution of ammonium sulphide containing 0·13 % sulphide-sulphur, both solutions containing 1 % soft soap. On the 7th day after spraying the shoots were examined; the "liver-of-sulphur" solution had had no more effect on the mildew than water, the mildew being now densely "powdery" with fresh conidiophores and conidia; the mildew on the shoot sprayed with ammonium sulphide was entirely sterile and obviously dying. No injury was caused to the foliage.

Summary of Observations. IV.

The experiments afford clear evidence that a 0·3 % solution of "liver-of-sulphur"—which, as already observed[1], is the strength which in this country has been generally recommended for use—is quite inefficacious as a fungicide against Hop and Gooseberry mildews. The patches are checked, more or less, for the first few days, but by about the 3rd day a fresh growth of conidiophores has taken place and, by the 5th to 8th day after spraying, the patches have become "powdery" again. The worthlessness of the 0·3 % solution of "liver-of-sulphur" (containing 0·13 % sulphide-sulphur) as compared with solutions of ammonium sulphide containing either 0·08 % or 0·16 % sulphide-sulphur was shown clearly in those experiments with Hops (Nos. 3 and 4) where mildewed leaves on the same plant were sprayed with the two solutions and also in the case of the Gooseberries sprayed in the open.

A solution containing 0·4 % of "liver-of-sulphur" (0·17 % sulphide-sulphur) without the addition of soft soap has no greater fungicidal value than the 0·3 % solution; with the addition of soft soap the patches are checked, but they are not killed entirely and are able to produce conidiophores by the 8th to 10th day.

A solution containing 0·6 % "liver-of-sulphur" (0·26 % sulphide-sulphur) greatly checks the mildew, which may remain dormant permanently or may produce a few tiny clusters of conidiophores. In two experiments, however, where this solution was used with respectively 1 % and 0·5 % soft soap, the patches of mildew after being greatly

[1] See p 474.

checked recovered, produced fresh conidiophores by the 5th to 8th day and were almost or quite powdery by the 12th day.

When the concentration of "liver-of-sulphur" is increased to 0·8 % (0·34 % sulphide-sulphur) the solution proved either completely or almost completely fungicidal.

It must be observed, however, when considering the fungicidal action of the solutions referred to above that with Gooseberries serious scorching occurs[1] at concentrations greater than 0·3 %, at which concentration it is found that the fungicidal value of this substance is nil.

V. AMMONIUM SULPHIDE (YELLOW).

Hops. 1914.

Exper. 1. *Solution containing* 0·04 % *sulphide-sulphur* (S.S.) *and* 1 % *soft soap.*

1st day. Mildew much checked.
3rd day. All the patches still dormant and sterile.
5th day. As above.
7th day. All the patches quite sterile and many of them dying.
12th day. All the patches dying or dead.

Exper. 2. *Solution containing* 0·04 % S.S. *and* 0·5 % *soft soap.*

1st day. Mildew checked; short conidiophores visible on most patches.
3rd day. As above.
5th day. All the patches still dormant.
8th day. All the patches completely sterile and many dying or dead.
12th day. Mildew just alive at two or three patches only (out of 20 patches), and producing there a very few conidiophores; the remaining patches dead.

Exper. 3. *Solution containing* 0·06 % S.S. *and* 1 % *soft soap.*

1st day. Mildew checked.
3rd day. Patches either sterile or with very short conidiophores.
5th day. All the patches quite sterile, dormant or dying.
8th day. As above.

Exper. 4. *Solution containing* 0·08 % S.S. *and* 1 % *soft soap.*

1st day. All the patches checked and dormant.
3rd day. All the patches still quite dormant.
5th day. All the patches dormant and sterile.
7th day. All the patches sterile, some dying.
9th day. As above.

[1] Salmon, E. S., "Report on Economic Mycology" (*Journ. S.-E. Agric. Coll.* XXII. p. 410 (1913) [1914]).

Expers. 5, 6, 7, 8. *Solution containing* 0·08 % S.S. *and* 1 % *soft soap.*

The results obtained in all these experiments were the same as that recorded above in Exper. 4, all the patches of mildew being sterile, and either dormant, dying or dead by the 9th to 12th day.

Exper. 9. *Solution containing* 0·08 % S.S. *and* 1 % *soft soap.*

In this experiment the action of the ammonium sulphide was compared with that of a solution of "liver-of-sulphur" containing 0·13 % sulphide-sulphur. The results are given under "*Liver-of-sulphur,*" Exper. 4 (see p. 487).

Exper. 10. *Solution containing* 0·16 % S.S. *and* 1 % *soft soap.*

In this experiment the action of the ammonium sulphide was compared with that of a solution of "liver-of-sulphur" containing 0·13 % sulphide-sulphur. The results are given under "*Liver-of-sulphur,*" Exper. 3 (see p. 487).

1915.

Exper. 1. *Solution containing* 0·02 % S.S. *and* 1 % *soft soap.*

1st day. Mildew checked; patches showing bases of conidiophores in large numbers.

4th day. Conidiophores remaining short.

7th day. Conidiophores still remaining short, even where very numerous; a very few isolated groups of taller conidiophores on a few patches; some patches quite sterile. The mildew obviously checked everywhere, and nowhere with "powdery" patches.

10th day. A few patches with small groups of conidiophores.

13th day. The patches increasing in size.

Exper. 2. *Solution containing* 0·03 % S.S. *and* 1 % *soft soap.*

1st day. Mildew much checked; mycelium more or less collapsed and flocculent; very few, weak, isolated conidiophores visible.

4th day. The patches all much checked and mostly sterile—a few with weak conidiophores.

7th day. Most of the patches sterile with collapsed mycelium; some patches with weak short conidiophores; three patches showing very small groups of vigorous erect conidiophores.

10th day. Four patches showing a very few erect conidiophores, the rest sterile.

13th day. Several patches with small tufts of conidiophores.

Exper. 3. *Solution containing* 0·04 % S.S. *and* 1 % *soft soap.*

1st day. Mildew much checked; mycelium more or less collapsed and flocculent; very few weak, isolated conidiophores visible.

4th day. A few patches showing a few weak conidiophores; most of the patches sterile.

7th day. As above.

10th day. A very few small tufts of conidiophores on a few patches on both leaves.

13th day. A few, small, almost powdery patches on both leaves.

Exper. 4. *Solution containing* 0·06 % S.S. *and* 1 % *soft soap.*

1st day. Mildew much checked; mycelium more or less collapsed and flocculent; very few, weak, isolated conidiophores visible.

4th day. The mildew greatly checked, but not apparently dead.

7th day. On two leaves all the patches showed the mycelium collapsed and sterile or bearing only weak, short conidiophores; on the other two leaves some patches were as above described, while others showed little tufts of vigorous, longer conidiophores.

10th day. On one plant the two fairly old leaves bore nearly all sterile patches, a few only showing freshly-produced, erect conidiophores; on one plant the two leaves each bore the majority of patches with very numerous erect, almost or quite powdery conidiophores.

Exper. 5. *Solution containing* 0·08 % S.S. *and* 1 % *soft soap.*

1st day. Mildew much checked; mycelium more or less collapsed and flocculent; very few, weak, isolated conidiophores visible.

4th day. The patches white, but quite sterile.

7th day. The mycelium everywhere floccoso-collapsed, usually sterile but occasionally with minute conidiophores.

10th day. All the patches quite sterile or occasionally with very short and weak conidiophores.

13th day. As above.

18th day. All the patches, though still white, quite sterile.

Exper. 6. *Solution containing* 0·08 % S.S. *and* 1 % *soft soap.*

1st day. The mildew greatly checked, the mycelium all collapsed and flocculent.

3rd day. A very few conidiophores present on a few patches.

9th day. The patches mostly completely sterile; a few scattered conidiophores present on a few patches.

11th day. As above.

Exper. 7. *Solution containing* 0·08 % S.S. *and* 1 % *soft soap.*

1st day. The mycelium everywhere collapsed.

3rd day. All the patches quite sterile.

7th day. The patches all sterile, and dormant or dying.

10th day. As above.

Exper. 8. *Solution containing* 0·11 % S.S. *and* 1 % *soft soap.*

1st day. Mildew greatly checked, with mycelium collapsed.

3rd day. Some short conidiophores present on some patches.

7th day. Mycelium of all the patches collapsed, sterile and apparently dying.

10th day. The mycelium of many of the patches almost disappeared.

15th day. A few scattered conidiophores visible on a few patches.

Exper. 9. *Solution containing* 0·13 % S.S. *and* 1 % *soft soap.*

1st day. Mildew greatly checked, with mycelium collapsed.

3rd day. All the patches showing completely collapsed and flocculent mycelium, quite sterile.

7th day. All the patches apparently dying.

10th day. As above.

15th day. All the patches with quite sterile, collapsed mycelium and evidently dying.

Exper. 10. *Solution containing* 0·13 % S.S. *and* 1 % *soft soap.*

1st day. Mildew greatly checked, with mycelium collapsed.

8th day. All the patches with collapsed, sterile mycelium.

11th day. The mildew still white, but quite sterile and dying.

Exper. 11. *Solution containing* 0·16 % S.S. *and* 1 % *soft soap.*

1st day. Mildew greatly checked, with mycelium collapsed, short conidiophores visible on a few patches; no injury apparent to the leaves.

3rd day. The short conidiophores still visible.

7th day The patches of mildew dead (with collapsed and partially disintegrated mycelium) on the young leaves, which showed no injury from the spray; the two older sprayed leaves curled up and turning brown, while the control leaves remained uninjured.

10th day. The two young sprayed leaves now turning yellow and dying, and falling at a touch.

Exper. 12. *Solution containing* 0·16 % S.S. *and* 1 % *soft soap.*

1st day. Minute injury apparent at the tips of two of the leaves; patches showing short, old conidiophores.

3rd day. The old conidiophores still visible.

8th day. All the patches with collapsed, sterile mycelium; the young leaves all seriously injured at their tips.

11th day. The tips of all the sprayed leaves scorched and brown; large brown dead areas where the patches of mildew had been.

Gooseberries. 1915.

With the object of ascertaining the behaviour of the leaves to ammonium sulphide before using the solution against American Gooseberry-mildew the following three experiments were carried out. Gooseberry bushes in pots in a greenhouse were used and the leaves, fully-grown berries and tips of shoots were sprayed. Two varieties of Gooseberry were used.

Exper. 1. (*Lancashire Lad.*) *Solution containing* 0·08 % S.S. *and* 1 % *soft soap.*

9th day. Very slight injury apparent in the form of the yellowing and dropping off of a few leaves.

11th day. No further injury. The whole of the injury caused was not appreciable from the practical (commercial) standpoint.

Exper. 2. (*Yellow Rough.*) *Solution containing* 0·08 % S.S. *and* 1 % *soft soap.*

9th day. A large number of the leaves turned yellow, resulting in a severe leaf-fall.

11th day. A large number of the leaves, and also of the berries, had fallen off. The injury caused was so severe as to preclude the possibility of the use of the spray on this variety[1].

Exper. 3. (*Lancashire Lad.*) *Solution containing* 0·16 % S.S. *and* 1 % *soft soap.*

8th day. Decided scorching effect on the older leaves, accompanied by a slight leaf-fall. Two berries fell off.

11th day. No further injury caused.

In the following experiments Gooseberry bushes, growing in the open, affected with American Gooseberry-mildew (*Sphaerotheca mors-urae*) in the "powdery" conidial stage, were sprayed.

Exper. 4. *Solution containing* 0·08 % S.S. *and* 1 % *soft soap.*

Six shoots, densely smothered with the mildew, were sprayed.

12th day. Four out of the six shoots bore only sterile mycelium; one shoot showed a few scattered conidiophores on the patches on two leaves; the remaining shoot had several minute, almost "powdery" patches on two leaves. It was clear that the solution had exerted a powerful fungicidal action.

Exper. 5. *Solution containing* 0·13 % S.S. *and* 1 % *soft soap.*

One shoot, densely smothered with the mildew in a "powdery" condition, was sprayed.

8th day. The mycelium everywhere dried up and completely barren. No injury caused to the leaves or tip of shoot. (NOTE. A similarly-affected shoot on the same bush was sprayed at the same time with a solution of "liver-of-sulphur" containing the same percentage (0·13 %) of sulphide-sulphur and 1 % soft soap. This had no fungicidal effect (see above, p. 490).)

Exper. 6. *Solution containing* 0·16 % S.S. *and* 1 % *soft soap.*

Six shoots, densely smothered with the mildew in a "powdery" condition, were sprayed.

12th day. The mildew on all six shoots was either dead, with the mycelium becoming disintegrated, or quite sterile and dying. No injury was caused to the leaves, berries or growing tips of the shoots, while the fungicidal action of the solution appeared to be complete.

[1] This variety has proved to be extremely susceptible to injury from the effects of sulphur (see Salmon, "Report on Economic Mycology" (*Journ. S.-E. Agric. College*, XXII. p. 405 (1913) [1914]).

Summary of Observations. V.

In 1914 proof was obtained that a solution of ammonium sulphide containing 0·04 % sulphide-sulphur was powerful as a fungicide, while solutions containing 0·06 %, 0·08 % and 0·16 % sulphide-sulphur proved uniformly efficacious in rendering the mildew permanently sterile, and usually in reducing it by the 5th to 8th day to a dead or dying condition.

In 1915 solutions containing 0·02 %, 0·03 % and 0·04 % sulphide-sulphur were found to be too weak to be a perfectly satisfactory fungicide. When the concentration of sulphide-sulphur was 0·08 % the solution was fungicidal in some cases, in others it was not quite so; at 0·13 % the solution proved to be invariably so.

The above remarks apply to the effect of ammonium sulphide against Hop-mildew. In 1915 ammonium sulphide containing 0·13 % or 0·16 % sulphide-sulphur proved fungicidal against American Gooseberry-mildew growing in the open, without causing any injury to the leaves or tips of the shoots, or disfigurement to the berries.

Patches of mildew treated with ammonium sulphide of a fungicidal strength remain white and but little altered in appearance to the superficial view, except that the mycelium may be in places more or less collapsed and flocculent; it remains persistently sterile until it passes into a dying condition. In Exper. 5, where a solution containing 0·08 % sulphide-sulphur was used on Hop-plants, the mildewed apex of a shoot (with the mildew completely encircling the stem) was sprayed, as well as the leaves bearing mildew. From the 1st day after spraying to the 18th day (when the experiment was concluded) the mildew on the upper leaves and on the stem remained white, although rendered completely sterile by the fungicide.

In Exper. 9, where a solution containing 0·13 % sulphide-sulphur was used, Hop-leaves bearing mildew, and also the healthy apex of a shoot and two healthy leaves, were sprayed *on both sides* of the leaf and *all round the shoot*; no injury resulted to the leaves or shoot. In one experiment (No. 12) the solution containing 0·16 % sulphide-sulphur caused serious injury to the Hop-leaves.

The only instance we can find recorded of the use of ammonium sulphide as a fungicide is that mentioned by Bourcart[1], who states that Dufour used it against *Dematophora necatrix* with negative results.

[1] Bourcart, E., *loc. cit.* p. 99.

VI. Ammonium Sulphide (Colourless).

Ammonium Hydrosulphide.

Exper. 1. *Solution (pale yellow) containing* 1·65 % S.S. *and* 1 % *soft soap.*

1st day. The patches checked, with the mycelium apparently more or less collapsed in places; some short conidiophores visible.

3rd day. The mildew apparently regrowing and forming fresh conidiophores.

7th day. The majority of the patches on each leaf now with vigorous tufts of almost or quite powdery conidiophores.

Exper. 2. *Solution (colourless) containing* 3·36 % S.S. *and* 1 % *soft soap.*

1st day. Patches slightly checked; hundreds of young conidiophores visible.

4th day. The majority of the patches, although still somewhat checked, showing groups of numerous, long conidiophores; the mycelium not collapsed and flocculent. On two out of the four leaves injury apparent in the form of a small brown "scorched" spot.

5th day. Some of the patches subpowdery.

7th day. The majority of the patches now "powdery."

Exper. 3. *Solution (yellow) containing* 3·31 % S.S. *and* 1 % *soft soap.* (This was the same solution as used above in Exper. 2, after one day's exposure to air in a half-filled stoppered bottle.)

2nd day. Mildew greatly checked.

3rd day. All the patches greatly checked, mostly sterile, but weak conidiophores visible here and there in several places on each leaf.

4th day. Mildew white, but dormant and sterile.

6th day. Patches mostly sterile, but some bearing a few weak scattered conidiophores.

10th day. Most of the patches on two leaves now with abundant conidiophores and almost powdery; on the third leaf many patches dead, but some patches bearing a few conidiophores.

Ammonium Sulphide (colourless).

Exper. 1. *Solution (colourless) containing* 1·68 % S.S. *and* 1 % *soft soap.*

1st day. Patches slightly checked; hundreds of young conidiophores visible. Slight traces of injury to some leaves.

4th day. Mildew still checked, with the mycelial hyphae apparently more or less collapsed in places; numerous groups of tall conidiophores produced freely on some of the patches. Distinct injury in the form of brown (dead) patches of leaf-cells on two leaves; similar injury, but more slight, on the four other leaves.

5th day. A few patches now subpowdery, but the mildew on the whole still checked.

7th day. The majority of the patches now "powdery" or subpowdery.

Exper. 2. *Solution (pale yellow) containing* 1·68 % S.S. *and* 1 % *soft soap.*

1st day. Mildew checked; all the patches showing more or less collapsed mycelium.

3rd day. All the patches sterile.

7th day. Most of the patches still sterile with collapsed mycelium; on each leaf, however, a few patches showed scattered erect new conidiophores.

10th day. No further growth of the mildew, which was practically entirely dormant and sterile.

Exper. 3. *Solution (yellow) containing* 1·68 % S.S. *and* 1 % *soft soap.* (This was the same solution as used above in Exper. 1, after one day's exposure to air in a half-filled stoppered bottle.)

2nd day. Mildew much checked, with collapsed mycelium.

3rd day. Mildew mostly sterile, but here and there a few short conidiophores; slight "scorching" evident at the tip of two of the leaves.

4th day. All the patches apparently becoming sterile; no further injury to the leaves.

6th day. The mildew everywhere sterile.

10th day. The mildew sterile and apparently dead on the old leaves; on the younger leaves several patches bearing fairly vigorous tufts of conidiophores.

Hydrogen Sulphide

Exper. 1. *Solution containing* 0·056 % S.S. *and* 1 % *soft soap.*

3rd day. The mildew quite unaffected; all the patches "powdery."

5th day. All the patches as "powdery" as those on the control leaves—in some cases more so; no injury to the leaf.

Summary of Observations. VI.

It will be seen from the foregoing experiments that the sulphur of hydrogen sulphide is without detrimental effect upon the mildew, although the concentration at which this was used is such as to be comparable only with our experiments with the weaker concentrations of yellow ammonium sulphide.

Ammonium hydrosulphide free from polysulphides is seen to be only slightly detrimental to the fungus and clearly is less efficacious as a fungicide than ammonium sulphide, also free from polysulphides, at the same concentration of sulphide-sulphur. At double the con-

centration, however, its behaviour towards the mildew does appear to approach that of the colourless ammonium sulphide.

When colourless solutions of ammonium hydrosulphide and of ammonium sulphide are allowed to stand exposed to atmospheric oxygen, they develop a yellow colour due to the formation of poly-sulphides in the solutions and it is observed that this change, although not altering appreciably the concentration of sulphide-sulphur, is attended by an increased fungicidal action of these solutions.

From these results it seems clear that the form in which sulphur functions as a fungicide in these solutions is that known as the poly-sulphide form.

VII. LIME-SULPHUR.

Hops. 1914.

Exper. 1. *Solution of* 1·005 *sp. gr.* (*containing* 0·7 % S.S.) *and* 0·125 % *saponin.*

1st day. Most of the patches well covered over by the deposit; a few patches showing the conidiophores uncovered or breaking through.

3rd day. As above.

5th day. Conidiophores still visible on some patches, but not apparently increasing.

8th day. Many of the patches dead; the few alive very weak.

12th day. A very few conidiophores visible on a few patches.

Exper. 2. *Solution of* 1·005 *sp. gr.* (*containing* 0·7 % S.S.) *and* 0·25 % *saponin.*

1st day. Many of the patches showing the conidiophores uncovered by the deposit.

3rd day. Nearly all the patches showing the conidiophores matted together; on a few patches the conidiophores were erect and apparently vigorous.

5th day. As above.

8th day. Nearly all the patches apparently dying or dead; in a very few cases a minute group of conidiophores was visible.

12th day. Some patches still showing a few conidiophores.

Exper. 3. *Solution of* 1·005 *sp. gr.* (*containing* 0·7 % S.S.) *and* 0·25 % *saponin.*

1st day. The patches all well covered over, some showing the conidiophores still erect, some with conidiophores collapsed.

4th day. No new conidiophores formed; all the patches still well covered.

6th day. All the patches remaining dormant.

9th day. All the patches dead.

Exper. 4. *Solution of* 1·01 *sp. gr.* (*containing* 1·43 % S.S.).

1st day. The patches well covered, their conidiophores erect and covered over by the "pellicle" formed by the dry spray.

3rd day. Patches apparently quite dormant; the conidiophores visible, but no fresh ones formed.

5th day. Some of the patches beginning to die; the conidiophores beginning to collapse.

7th day. The mildew dead; the leaves now beginning to turn yellow.

Exper. 5. *Solution of* 1·01 *sp. gr.* (*containing* 1·43 % S.S.) *and* 0·25 % *saponin.*

1st day. The patches well covered over.

3rd day. All the patches quite dormant.

5th day. All the patches apparently dying or dead.

7th day. All the patches dead; no injury to the leaf.

Exper 6. *Solution of* 1·01 *sp. gr.* (*containing* 1·43 % S.S.) *and* 0·25 % *saponin.*

1st day. All the patches well covered over; some showing conidiophores still erect, some with conidiophores collapsed.

4th day. The conidiophores still visible on the patches; but no fresh ones being produced; the mycelium remaining dormant.

6th day. All the patches quite dormant.

10th day. Two patches showing a very few weak scattered conidiophores; the remaining patches all dead.

Exper. 7. *Solution of* 1·01 *sp. gr.* (*containing* 1·43 % S.S.) *and* 0·25 % *saponin.*

1st day. Most of the patches well covered over with the deposit; some of the patches showing the conidiophores breaking through the deposit.

3rd day. All the patches showing matted or collapsed conidiophores.

5th day. All the patches still dormant.

8th day. All the patches dead.

Exper. 8. *Solution of* 1·01 *sp. gr.* (*containing* 1·43 % S.S.) *and* 0·125 % *saponin.*

1st day. All the patches well covered over with the deposit.

3rd day. As above.

5th day. Conidiophores, more or less collapsed, visible on most of the patches; no fresh formation of conidiophores.

8th day. All the patches dead; the mycelium and conidiophores shrivelled up.

Summary of Observations. VII.

As it is impossible to use soap with lime-sulphur solutions, it was decided to substitute saponin so as to make the experiments comparable as far as possible with those where soap was used. At 1·005 sp. gr. the lime-sulphur solution was either quite, or was very nearly, fungicidal; at 1·01 sp. gr. it was almost invariably so.

These results are corroborative of the results previously obtained by one of us[1] in certain experiments in which lime-sulphur at 1·01 sp. gr. proved completely fungicidal against *S. Humuli*, killing the growing fungus and preventing infection of the leaf by conidia.

VIII. IRON SULPHIDE.

Hops. 1914.

Exper. 1. *Solution containing* 0·2 % *iron sulphide.*

1st day. Mildew only slightly checked; conidiophores still mostly erect.

3rd day. Some of the patches (perhaps those where the spray did not permeate) now almost "powdery"; others still checked.

5th day. The majority of the patches now with numerous erect conidiophores.

7th day. A considerable number of the patches now "powdery."

Exper. 2. *Solution containing* 0·2 % *iron sulphide and* 0·25 % *saponin.*

1st day. Mildew only slightly checked; conidiophores still mostly erect and vigorous.

3rd day. Some of the patches nearly "powdery."

5th day. Most of the patches now with very numerous erect conidiophores.

7th day. All the patches now "powdery" or nearly so.

Exper. 3. *Solution containing* 0·2 % *iron sulphide and* 1 % *soft soap.*

1st day. Mildew checked.

3rd day. All the patches still more or less checked.

5th day. The patches now showing very numerous erect conidiophores.

7th day. All the patches now "powdery" or nearly so.

Exper. 4. *Solution containing* 0·3 % *iron sulphide and* 0·5 % *soft soap.*

1st day. Mildew much checked; a few scattered short conidiophores visible.

3rd day. All the patches quite dormant and apparently dying.

[1] Salmon, E. S., "Report on Economic Mycology" (*Journ. S.-E. Agric. College*, XIX, p. 345 (1910)).

5th day. As above.

8th day. The majority of the patches dead on all the three leaves; on each of the two lower leaves three patches only were alive—one bearing a minute group of conidiophores, the remaining two dormant and sterile; on the upper leaf several patches bore a group of conidiophores.

12th day. The mildew still feebly alive at a few spots on the two lower leaves; on the upper leaf several of the patches showed a more or less vigorous growth and bore conidiophores.

Exper. 5. *Solution containing* 0·3 % *iron sulphide and* 1 % *soft soap.*

1st day. Mildew checked.

3rd day. All the patches quite sterile and dormant.

5th day. As above.

8th day. Patches all apparently dying.

12th day. As above.

Exper. 6. *Solution containing* 0·3 % *iron sulphide and* 1 % *soft soap.*

1st day. Mildew greatly checked, many of the patches apparently killed.

2nd day. Nearly all the patches dead; a few patches near the edge of the leaf developing a few conidiophores.

5th day. As above.

7th day. The few patches noted above remaining alive and bearing small isolated groups of conidiophores.

11th day. The groups of conidiophores at the few patches more numerous.

Exper. 7. *Solution containing* 0·6 % *iron sulphide and* 0·5 % *soft soap.*

1st day. The mildew greatly checked or killed.

3rd day. All the patches quite dormant and apparently dying.

5th day. All the patches dead.

Exper. 8. *Solution containing* 0·6 % *iron sulphide and* 1 % *soft soap.*

1st day. All the patches well covered over with the brown deposit, and showing only collapsed conidiophores.

4th day. All the patches dead; leaf uninjured.

Exper. 9. *Solution containing* 0·6 % *iron sulphide and* 1 % *soft soap.*

1st day. Mildew very greatly checked; most of the patches apparently killed.

3rd day. Nearly all the patches dead; only one or two on each leaf showing a few of the conidiophores remaining.

5th day. All the patches apparently dead.

12th day. All the patches dead.

Exper. 10. *Solution containing* 0·45 % *iron sulphide and* 1 % *soft soap.*

1st day. All the patches of mildew completely covered by the spray and apparently killed; no injury to the leaves apparent.

4th day. All the patches of mildew dead; the youngest sprayed leaf showing injury at the tip and margin.

6th day. The youngest leaf now severely injured; the remaining leaves unaffected.

9th day. No further injury to the leaves.

Exper. 11. *Solution containing* 0·9 % *iron sulphide and* 1 % *soft soap.*

1st day. All the patches of mildew completely covered by the spray and apparently killed; the youngest of the sprayed leaves injured and shrivelled.

4th day. All the patches of mildew dead; injury apparent to the tip and margins of another leaf—the remaining leaves (four) not injured.

9th day. No further injury to the leaves.

Summary of Observations. VIII.

The iron sulphide solution dries at once to a rusty-brown deposit which covers over uniformly the patches of mildew[1]. A 0·3 % solution, with a 1 % solution of soft soap, is almost satisfactory as a fungicide; a 0·6 % solution, with either a 0·5 % or 1 % solution of soft soap, is invariably fungicidal. No injury was caused to the foliage. In the above experiments the iron sulphide was made by the method (i) (described at p. 480) under which it was possible for a small quantity of ammonium sulphide to be present. In two experiments (carried out in 1915) the iron sulphide was made on the method (ii) (described at p. 480) under which no ammonium sulphide was present. In the first experiment (No. 10) a 0·45 % solution of iron sulphide was used; it proved completely fungicidal by the 4th day. Severe injury was caused to the youngest Hop-leaf, the others remaining uninjured. In the second experiment (No. 11) a 0·9 % solution was used; the mildew was killed immediately; two out of the six leaves were injured at the tips and margins.

[1] If used on Gooseberries it would be inferior to the yellow ammonium sulphide solution because it would disfigure the berries; it would have the advantage, however, over lime-sulphur in that the markings on the sprayed berries would not be liable to be mistaken for spots of mildew by incompetent inspectors at the market.

THEORETICAL CONSIDERATIONS.

Although a considerable literature is to be found dealing with alkaline sprays—particularly those known as "lime-sulphur" and "liver-of-sulphur"—there appears to be little of a definite character known indicating which of the several constituents of these mixtures possess the fungicidal properties associated with these spray-fluids.

A consideration of the results obtained in our experiments makes it evident that certain of the views referred to above (p. 475) are erroneously founded, although sufficient data have not yet been obtained on which to base a full discussion of the problem.

It has been claimed that solutions of "liver-of-sulphur" are fungicidal mainly by reason of the free alkali they contain initially or by reason of that which may become available subsequent to spraying. That this explanation does not hold good appears clear from the following evidence based on results obtained in our experiments with solutions of caustic soda and of a solution of "liver-of-sulphur" which is fungicidal. Accepting a 1 % solution of the sample of "liver-of-sulphur" used in our experiments as being definitely fungicidal, calculation shows that this cannot contain more free alkali than the equivalent of 0·4 % NaOH, whereas a solution containing 0·5 % NaOH proved to be not fungicidal. Thus it seems clear that a concentration of "liver-of-sulphur" which is entirely fungicidal will not contain at any time a sufficient concentration of free alkali to destroy the mildew.

Equally clear evidence of the inefficacy of free alkali has been found in the case of yellow ammonium sulphide. Solutions of this compound which cannot, by reason of their mode of preparation, contain as much as 0·4 % total ammonia are found to be fatal to the mildew (*vide* Yellow Ammonium Sulphide, Expers. 9, 10 and 11); whereas our experiments with solutions of ammonia show that this alkali up to 2 % concentration is not detrimental to the fungus.

The negative results obtained in our experiments with solutions of sodium carbonate also give the same evidence that the weak alkaline nature of the spray-fluid is not responsible for fungicidal action.

In view of the fact that the ammonium sulphide solution used—which proved so efficacious—contained no sulphate and only indeterminably small quantities of thiosulphate and of sulphite, this discounts very largely the suggestion that any of these substances are responsible for the fungicidal action observed. It was not surprising therefore to find that sodium thiosulphate exhibited no fungicidal properties.

A comparison of the results of our experiments makes it clear that the proportion of "sulphide-sulphur" present is no index of the efficacy of a spray-fluid[1]. It will be seen that a solution of yellow ammonium sulphide containing 0·13 % sulphide-sulphur is invariably fungicidal, whereas a solution containing 0·13 % sulphide-sulphur in the case of "liver-of-sulphur" has no fungicidal value—the concentration at which the latter substance becomes fungicidal is 0·34 % sulphide-sulphur.

Further, solutions containing as much as 1·6 % and 3·3 % sulphide-sulphur in the case of a colourless solution of ammonium hydrosulphide and a colourless solution of ammonium sulphide respectively failed to do more than check the fungus temporarily.

It seems evident, therefore, that the soluble polysulphides present are the substances of fungicidal value. The question which then arises is whether the property of killing the fungus is due to the direct action of the polysulphides themselves or whether it is due to the sulphur which is deposited when these compounds decompose.

With the object of gaining information on this point determinations have been made of the amount of sulphur which is deposited from a solution of colourless ammonium hydrosulphide and from a solution of yellow ammonium sulphide when exposed to air under conditions similar to those obtaining when these substances are used as spray-fluids.

Definite quantities of these solutions were absorbed on tared filter-papers and allowed to dry in the air alongside similar filter-papers which served as controls and as counterpoises in weighing. The solution of ammonium hydrosulphide used contained 5·93 % of "sulphide-sulphur" (somewhat less than the stock solution used in Exper. 2, i.e. 6·7 %) and it was found to deposit 0·356 grm. per 100 c.c. of solution. The solution of yellow ammonium sulphide contained 2·19 % of "sulphide-sulphur" (the stock solution from which the spray-fluids have been prepared) and, in this case, the deposit of sulphur amounted to 2·56 grms. per 100 c.c. of solution.

From these estimations it is calculated that when the above-mentioned solutions are diluted in the manner followed when preparing such solutions for spraying purposes 100 c.c. of the ammonium hydrosulphide spray-fluid (containing in this case 2·96 % sulphide-sulphur:

[1] In an article in the *Journ. Board of Agric.* 1914, vol. XXI. p. 236, giving the analyses of various commercial samples of "liver-of-sulphur," the assumption has been made that the fungicidal value of any sample is determined by its sulphide-sulphur content.

compare Expers. 1 and 2) would deposit 0·178 grm. of sulphur; and 100 c.c. of the yellow ammonium sulphide spray-fluid (containing 0·13 % sulphide-sulphur: compare Expers. 9 and 10, p. 494) would deposit 0·160 grm. of sulphur.

This experiment was repeated three times and closely similar results were obtained in each case showing that the amount of sulphur actually deposited from these two kinds of alkaline sulphide solutions is not widely different. It would seem therefore that a larger deposition of sulphur occurred in the case of our Expers. 1 and 2 with ammonium hydrosulphide than in Expers. 9 and 10, p. 494 with yellow ammonium sulphide. In view of the considerable interest attaching to this part of the subject, it is proposed to repeat and extend these experiments during the coming season.

From the results so far obtained the conclusion is reached that yellow ammonium sulphide is valuable as a fungicide because of the polysulphides contained in solution and that these probably act as such and not by virtue of sulphur which is deposited. It is thought that when a solution of ammonium hydrosulphide is allowed to evaporate in the air the oxidation which takes place does not largely lead to the formation of polysulphides but mainly to the direct deposition of sulphur.

General Summary and Conclusions.

1. Solutions of such substances as "liver-of-sulphur" and ammonium sulphide when used against the "powdery mildews" (*Erysiphaceae*) in the actively-growing conidial stage require the addition of some substance such as soft soap in order to increase their wetting properties and so secure complete fungicidal action.

2. Solutions of "liver-of-sulphur" of the strength recommended by authors generally (0·2 % to 0·4 %) for use against the "powdery mildews" are not fungicidal against the growing mycelium. When the concentration is increased to 0·6 % or 0·8 % this substance begins to be fungicidal.

3. A solution of yellow ammonium sulphide has proved to be completely efficacious against the Hop-mildew (in the greenhouse) and the American Gooseberry-mildew (in the open). The use of this material has the distinct advantage that, unlike lime-sulphur, it leaves no visible deposit and does not therefore disfigure the fruit. Solutions of definite fungicidal strength have caused no "scorching" injury to the foliage of the Hop or Gooseberry.

4. Iron sulphide, which has been favourably reported upon in field experiments, proved on close observation to have, at a concentration of 0·6 %, a remarkably quick fungicidal action on the Hop-mildew. When made by a method which leaves a trace of ammonium sulphide present it has proved to be quite harmless to foliage and is in a condition which enables it to be applied as a fine spray.

5. The presence of free alkali in solution is not the determining factor in the fungicidal value of the alkaline sulphide solutions used.

6. The proportion of sulphide-sulphur present is no index of the fungicidal value of solutions of alkaline sulphides.

7. It appears that the polysulphides contained in a solution of yellow ammonium sulphide act fungicidally as such and not by virtue of the sulphur which is deposited when these compounds decompose.

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SOME OBSERVATIONS ON THE FLORA AND FAUNA OF FLOODED FENLAND.

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ON January 3rd, 1915, the Little Ouse burst its right bank not far from the Feltwell 2nd District Pumping Station, and as a result thousands of acres of fenland became flooded. The portion of the flooded land on which the following observations were made is a part of Southery fen situated near Southery, Norfolk. It lies between Peckett's Farm and Turf Fen Farm, and belongs to the Norfolk County Council. This land is some distance from the place where the burst occurred, and as a consequence there was no deposit of silt. The height of the flood here was about nine feet. The water was gradually pumped off and the land cleared by September, 1915.

Heavy rains kept patches of the land very wet until December, 1915, when the following observations were made. After the water had all been cleared from the land, the most striking feature was that a large portion of the land was completely covered by the alga *Cladophora flavescens*, known locally as "blanket" or "carpet weed." This mat of the dead and dying alga was about an inch thick and could be lifted up from the soil in the same way as a carpet can be lifted from the floor (Pl. V, fig. 1). When dry this carpet made ploughing very tedious, as the plough frequently became clogged. On some of the fields it was raked into heaps and burnt before ploughing.

In the damper spots small patches of *Vaucheria terrestris* and *Enteromorpha intestinalis* were found together with the *Cladophora*.

Another noticeable feature was the presence of *Polygonum amphibium* in great abundance. Some fields were so thick that from a distance the reddish brown colour of these plants only was noticeable, the blanket weed being underneath.

Polygonum amphibium usually floats and reaches the surface of the water in which it grows, so from the length of these plants (many of which were over nine feet long) it was possible to tell the depth of the water on the different fields. Most of the plants were carrying a good supply of seed so that it may prove troublesome during the next few years. It caused more hindrance to ploughing than the "blanket weed."

Chara hispida was present in great abundance for a distance of about sixty feet on each side of the dykes. Sometimes it was abundant on one side of the dyke and not on the other. On the rest of the field only small patches could be found (Pl. V, fig. 2).

Another smaller species of *Chara* was found but not very frequently.

As the remains of the *Charas* are almost entirely composed of calcium carbonate, they should prove of considerable value in neutralizing the acidity of the soil, and it will be interesting to note in those fields which receive no dressings of lime, chalk, or similar materials, if the crops grow better where the deposits of *Chara* were thickest, viz. near the dykes.

In places, *Alisma plantago*, the water plantain, was prevalent and had set seed (Pl. VI, fig. 3).

Occasional plants of *Typha latifolia* were met with, but these were cut down before the land was ploughed.

On the dyke sides *Arundo phragmites* was growing luxuriantly.

The following is a list of the plants found on the arable land:

Polygonum amphibium	*Polygonum aviculare*
Alisma plantago	*Veronica beccabunga*
Typha latifolia	*Ranunculus aquatilis* var.
Mentha aquatica	*Oenanthe fluviatilis*
Agropyrum repens	*Lythrum salicaria*
Agrostis alba	*Senebiera coronopus*
Cnicus arvensis	*Rumex hydrolapathum*
Callitriche verna var.	*Glyceria aquatica* (near the dykes)

Grass Land. Two pastures were examined, situated respectively near the farm buildings of Peckett's Farm and Turf Fen Farm. On both of these all the useful grasses were killed. Both were thickly covered with "blanket weed," and occasional specimens of *Polygonum amphibium* were found. *Agropyrum repens* was present in abundance, and occasional specimens of *Agrostis alba* were found.

At Turf Fen Farm, *Potentilla anserina* was fairly abundant, as was

also the moss *Amblystegium riparium*. Both of these pastures are destined to be ploughed up.

As a result of the flood, many of the stacks were moved from the stackyards, and some floated considerable distances. After the water had subsided, the stacks became covered with plants up to the water level.

The following were found growing on old straw stacks:

Matricaria inodora	*Lapsana communis*
Stellaria media	*Stachys palustris*
Viola tricolor	*Polygonum aviculare*
Galeopsis versicolor	*Plantago major*
Chenopodium album	*Agrostis alba*
Galium aparine	*Mentha aquatica*
,, *uliginosum*	*Senecia vulgaris*

The flora of the farmyard was very varied, many of the plants probably originating in the straw stacks.

Polygonum amphibium	*Lychnis Githago*
,, *persicaria*	*Plantago major*
,, *fagopyrum* (buckwheat)	*Stachys palustris*
,, *aviculare*	*Capsella bursa pastoris*
Sinapis arvensis	*Ranunculus repens*
Alisma plantago	,, *sceleratus*
Galeopsis versicolor	*Nasturtium officinale*
Chenopodium album	*Barbarea vulgaris*
,, *urbicum*	*Rumex obtusifolius*
Urtica urens	*Poa annua*
,, *dioica*	,, *trivialis*
Lapsana communis	*Dactylis glomerata*
Mentha aquatica	*Agropyrum repens*
Stellaria media	*Agrostis alba*
Carduus nutans	

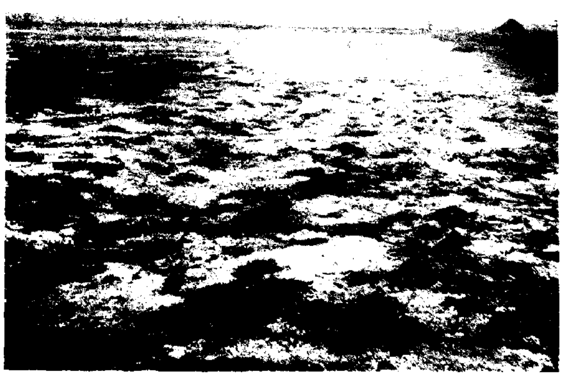
In the gardens all flowers, vegetables, box hedges and gooseberry bushes were killed with the exception of horse radish. All the willow trees along the sides of the dykes formed dense masses of adventitious roots above the soil level and below the flood water level (see Pl. VI, fig. 4). The soil reacted slightly acid to litmus and nitrifying organisms were found to be present.

FAUNA.

Snails. It was thought probable that some of the flooded land might be infested with *Limnaea truncatula*—the snail which carries the Liver-fluke of sheep—but none were found.

Cladophora flavescens ("blanket" or "carpet weed") and *Polygonum amphibium*.

Fig. 1



The zone of *Chara hispida* spreading from the dyke on the right; with scattered plants of *Alisma plantago*.

Fig. 2

Area densely covered with *Alisma plantago* with a patch of *Cladophora flavescens* in the foreground.

Fig. 3

A large number of empty shells and a few living specimens of the ›llowing were found:

Limnaea pereger	*Planorbis umbellicatus*
„ *stagnalis*	„ *corneus*
Planorbis vortex	*Bythinia tentaculata*

Eelworms. The presence of eelworms was tested for by placing mall pieces of lean meat and mangold on the surface of the soil in the ıboratory and examining at intervals. No eelworms were found.

Earthworms. A few earthworms were found in the stackyards, ut none in the fields.

Insects. Large numbers of bloodworms, the larvae of various species of *Chironomus*, were found. These were present in great abundance all over the area.

The only other insect found in the fields was a larva of a hover fly.

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